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Machine-Shop Practice

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BORING-MILL WORK
WORKING CHILLED IRON
BENCH, VISE, AND FLOOR WORK
ERECTING

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PREFACE

The volumes of the International Library of Technology are made up of Instruction Papers, or Sections, comprising the various courses of instruction for students of the International Correspondence Schools. The original manuscripts are prepared by persons thoroughly qualified both technically and by experience to write with authority, and in many cases they are regularly employed elsewhere in practical work as experts. The manuscripts are then carefully edited to make them suitable for correspondence instruction. The Instruction Papers are written clearly and in the simplest language possible, so as to make them readily understood by all students. Necessary technical expressions are clearly explained when introduced.

The great majority of our students wish to prepare themselves for advancement in their vocations or to qualify for more congenial occupations. Usually they are employed and able to devote only a few hours a day to study. Therefore every effort must be made to give them practical and accurate information in clear and concise form and to make this information include all of the essentials but none of the non-essentials. To make the text clear, illustrations are used freely. These illustrations are especially made by our own Illustrating Department in order to adapt them fully to the requirements of the text.

In the table of contents that immediately follows are given the titles of the Sections included in this volume, and under each title are listed the main topics discussed.

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CONTENTS

NOTE.—This volume is made up of a number of separate Sections, the page numbers of which usually begin with 1. To enable the reader to distinguish between the different Sections, each one is designated by a number preceded by a Section mark (§), which appears at the top of each page, opposite the page number. In this list of contents, the Section number is given following the title of the Section, and under each title appears a full synopsis of the subjects treated. This table of contents will enable the reader to find readily any topic covered.

BENCH, VISE, AND FLOOR WORK
(Continued)

ERECTING, § 25, § 26

BORING-MILL WORK

BORING MILLS AND THEIR OPERATION

CLASSES OF BORING MACHINES

1. Boring mills have been developed from the lathe and, in principle, are very similar to it. There are two types of boring mills, the *vertical* and the *horizontal*. Although these machines are known as boring mills, both are used for other operations.

The **vertical boring mill** may be thought of as a *face-plate lathe* so constructed that the spindle is vertical and the work, which is clamped to a table, revolves. The machine is adapted to turning as well as boring, and is often called a *boring and turning mill.*

The **horizontal boring mill** may be thought of as a lathe in which the work is clamped to the bed, and the cutting tool revolves, the tool being carried by a boring bar fitted to the spindle of the machine. Drilling and milling operations as well as boring may be performed on this machine, for which reason it is sometimes called the *horizontal boring, drilling, and milling machine.* Horizontal boring mills may be subdivided into the simple type of horizontal boring machine most commonly found in machine shops; the horizontal floor mill, used generally where large work is done; and special boring mills for cylinder boring and for boring spherical bearings.

VERTICAL BORING-MILL WORK

2. Large Vertical Boring Mill.—In Fig. 1 is shown the type of vertical boring mill most used for medium and large

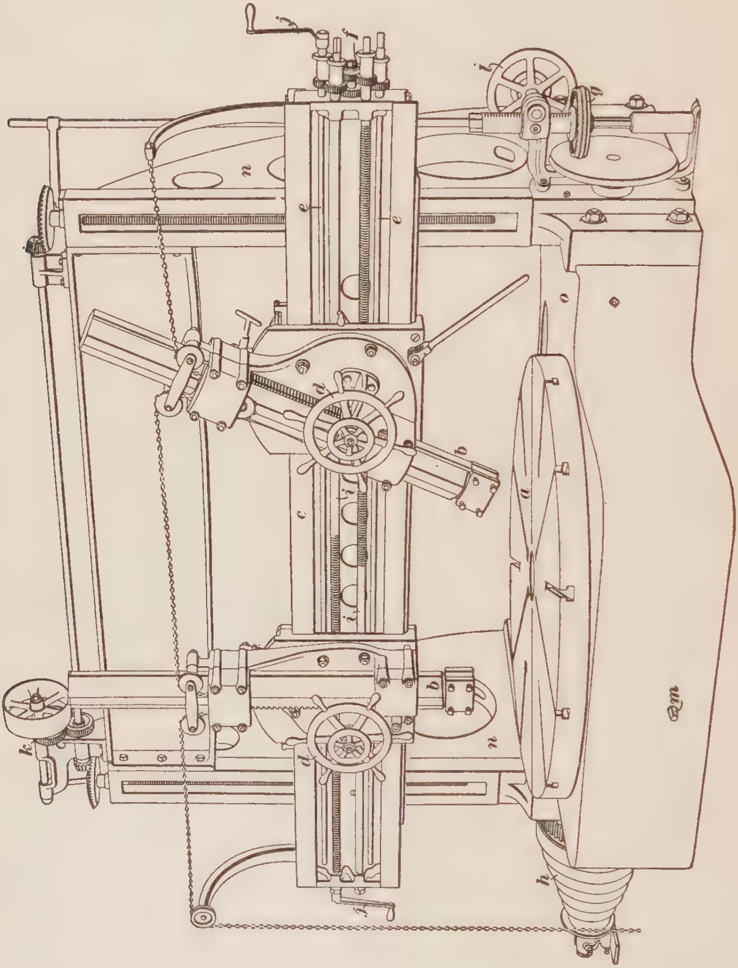


FIG. 1

work. The work is clamped on a rotating table *a* containing slots for **T**-head bolts, and the cutting tools are carried in the

lower ends of the boring bars *b*. The boring bars are carried in saddles, which travel on the cross-rail *c*. The tools are raised and lowered by means of the hand wheels *d*, or by power through the feed-rods *e*. These rods are geared to the boring bars, and connect by means of gearing at *f* and a friction wheel and disk at *g*, through the bed of the machine, to the driving cone *h*. The driving cone is driven by belt from an overhead countershaft. The tools are fed horizontally by means of the feed-screws *i*, which traverse the saddles on the cross-rail. The screws may be operated by hand by means of the handles *j*, or by power through the gearing at *f* and the friction wheel and disk at *g*. The cross-rail is raised and lowered by power through the pulley and gearing at *k*. This pulley is driven by belt from a separate countershaft. Instead of driving by belt, machines of this type are often driven by motors, one motor being used to operate the table, including the feeds, and another to operate the cross-rail.

3. The control of the feed is effected by the friction wheel and disk at *g*. The wheel can be raised and lowered by turning the hand wheel *l*; the position of the disk does not change. As the wheel approaches the outer edge of the disk it makes a greater number of revolutions at each revolution of the disk than it makes when near the center. When the friction wheel is carried below the center of the disk and moved towards the outer edge, the same range of speeds is maintained but the direction of motion is reversed. A great variety of both vertical and horizontal feeds in either direction is thus obtained, while clutches and reversing mechanisms in the saddles place the tool under the operator's control. Counterweights are provided in order that the various parts may be operated easily. Instead of the friction feed used on this machine, many boring mills are equipped with the gear-box feed described elsewhere.

4. The arrangement of the feeds is such that one tool may be turning the outside of a piece while the other is boring, or both may be either boring or turning on the same or different diameters, or one tool may be facing the top while the other

may be either boring or turning. Conical turning or boring may be done by setting the head at an angle, as shown at the right hand in Fig. 1. When working on different diameters, the tool on the smaller diameter has a slower cutting speed than that cutting on the larger, and the speed must be adjusted for the larger diameter. These operations are virtually the same as those carried on in the lathe, and the tools used for these operations in the two machines are identical.

5. The table is rotated by means of an internal gear on its lower side, and a pinion that is connected through a pair of bevel gears to the driving cone *h*. A back gear like that on a lathe is provided, which, with the different steps on the cone, furnishes a wide range of speeds.

The table is supported in the center on a long vertical spindle running in a bearing near the top and another bearing at the bottom, while a step bearing at the lower end takes the thrust. The rim of the table runs in a groove in the bed, which is flooded with oil, and, when running slowly on heavy work, the greater part of the weight is taken on this rim.

Provision is made for raising and lowering the table when running at high speeds on light work, so that the entire load is taken by the spindle. A screw *m* connects with a wedge under the thrust bearing by means of a nut and lever, and, by turning the screw in one direction, the wedge is forced in, while rotation in the opposite direction withdraws it.

6. Extension Boring Mill.—In shops where there is occasionally a piece of large diameter to be turned, but where there is not enough very large work to warrant the purchase of a large boring mill, an extension boring mill may be used to advantage. On an extension mill, the bed *o*, Fig. 1, is made with an extension at the back and with ways on top, on which the housings *n* rest, and on which they may be moved back, so as to accommodate a larger piece on the table. The cross-rail is, of course, carried back with the housings, and, to do boring, it is necessary to use a vertical boring bar supported in an extension arm attached to the cross-rail or to place one of the heads taken from the cross-rail on the extension arm,

which is not shown in the illustration. Holes may be bored by feeding the boring bar, which does not revolve, vertically; and the work may be turned and faced by feeding the head along the extension arm. When convenient, the boring bar may rest in the center of the table. This extension provision in a mill designed for the average work of a shop will enable larger pieces to be machined at a comparatively small increase of cost for machine tools.

7. Attachments for Vertical Boring Mills.—A **rail head** carrying a tool bar is often placed on one of the uprights of the machine. This head is conveniently located to undercut the outer surface and to turn the lower side of large work.

A **rear column,** carrying a tool head and bar, is sometimes attached to the back part of the bed. The rear column, like the rail head, is used to turn outer surfaces and to turn the lower side of large work. It may be used singly, but is generally used at the same time as the tool heads on the cross-rail. The rear column, rail head, and cross-rail heads may all be used at the same time.

8. Small Vertical Boring Mill.—A small vertical boring and turning mill is shown in Fig. 2. In principle, this machine is identical with the large machine previously described. It has, however, a turret head, a feed-gear box, and a fine feed adjustment, which devices are seldom found on the larger machines.

In the illustration, the feed-gear boxes *a*, by which the cross-feed screw and the feed-rod located in the cross-rail are driven, are shown on each side of the machine. By their use, any required feed may be obtained, the operation being similar to that of the feed-gear boxes used on lathes. The gears enclosed in them drive the feed-rods positively. They take the place of the wheel-and-disk friction drive shown in connection with the larger machine.

The machine has a swiveling head *b*, and a head *c* consisting of a five-sided turret in which boring and chucking tools are held.

9. The slots in the table *d* are so arranged that chuck jaws or jigs may be secured to the table. The work is then held in the chuck thus formed or in the jig when machining. A large variety of work that can be done on a lathe can be more conveniently done on a machine of this type. The mill is also much more rigid than the lathe.

To facilitate the fine feed adjustment, **capstan collars,**

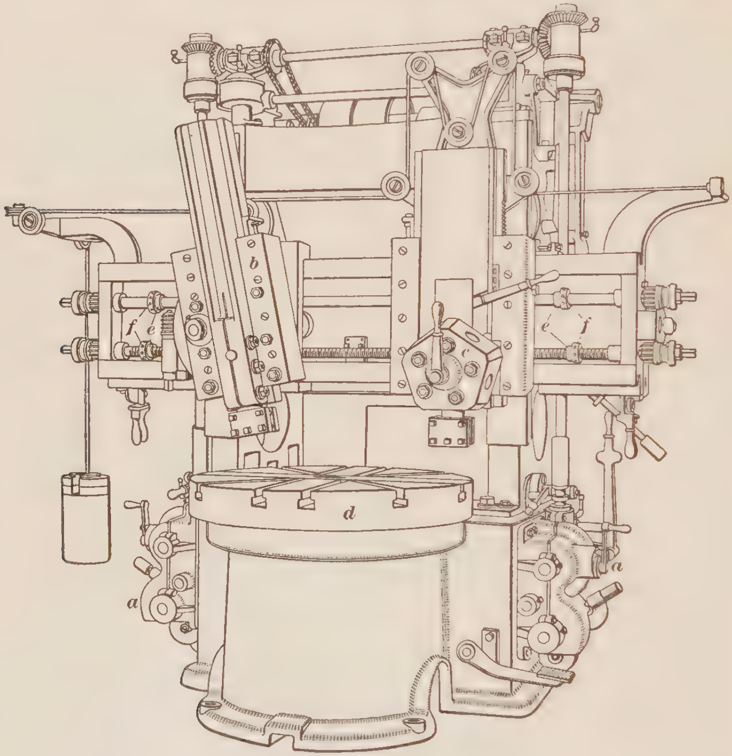


FIG. 2

which are splined collars having holes in which a pin may be inserted to turn them, are used. When operating a machine equipped with capstan collars, the tools are moved approximately to their working positions in the usual way. To make the fine feed adjustment, the capstan collars *e*, which are free to slide on the feed-rod and screw and which are prevented from

turning by keys, are moved close to the tool heads. A short pin is inserted in one of the holes *f* of the collar and the rod or screw is turned the required amount. The advantage of the capstan collars is that they are more conveniently located to the operator than are the crank handles.

10. Setting Up Work on Vertical Boring Mill.—The horizontal table of the vertical boring mill makes the setting of work easier than in the lathe, as the piece can be placed loosely on the table and need not be secured while the settings and adjustments are being made. Small work is often held in a chuck similar to a lathe chuck, and large work is generally blocked up on parallel pieces and held by clamps, angle plates, and drivers, which are devices that prevent the work from turning on the table. Owing to the stiffness of the table, heavier cuts can usually be taken on the boring mill and more tools used at once than in a similar lathe operation.

The three following requirements may be taken as a guide when setting work. The piece must be set with the circumference to be finished exactly concentric with the center of rotation. In other words, it must be set so that it runs true enough to turn to size. The work must be set so that the center line, or axis, will be perpendicular to the top of the table. If the lower surface is irregular, the work must be blocked up to prevent springing and to bring the work level. The work must then be gripped with jaws, or clamped, as on the planer, with drivers to take the twisting strain due to the pressure of the cut. The drivers may be angle irons or plates or other braces to prevent the work from turning on the table while the cuts are taken.

11. Examples of Vertical Boring-Mill Work.—A plain piece of work such as an engine crank-disk, Fig. 3, for example, is held in the chuck jaws of the boring mill with the face *a* nearest the table, precisely as a piece of similar form would be held in a lathe face-plate chuck. The center *b* of the crank is then bored, the top *c* faced, and as much of the outside turned as the jaws will permit. The piece is next turned over, gripped in the jaws, and adjusted so that the turned and bored parts

will run true. The face a and the unfinished part of the outside are now machined.

The center of the crankpin hole d is next accurately located at the correct distance from the crank center and a circle the size of the hole is drawn around it. The crank-disk is then set flat on the table enough out of center to bring the pin hole central. A pointer held in the tool holder is brought over the circle and the crank-disk adjusted until the circle follows the pointer. The disk is then securely clamped and enough weight added to the table to balance the crank and make the table run smoothly. The table is then speeded up and the small hole is bored to size.

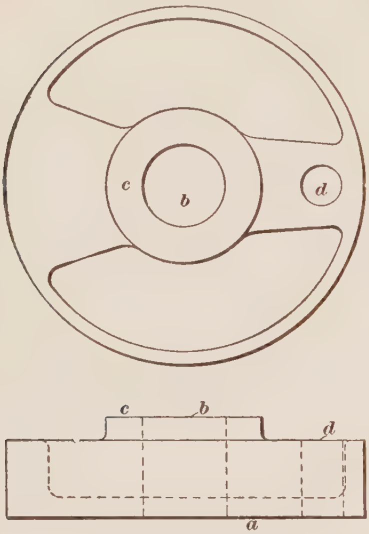


FIG. 3

12. Fig. 4 illustrates how an irregular piece may be secured on the table. Before setting a large piece, the table must be carefully cleaned and lowered so that the weight is taken on the outer rim of the bed as well as by the step bearing. When this is neglected, there is danger of injuring the step bearing and also of springing the table. The piece is then placed on the table, set approximately central, and leveled up by blocking at regular intervals. In Fig. 4, screw jacks a are used in leveling up. When the piece is approximately level, a small stick held lightly in the tool holder is brought very near the circumference or surface to be turned, and the table is rotated slowly. Careful observation of the distance between the part and the stick will show in which direction it must be moved to bring it perfectly central. The distance from the stick to the upper surface should be observed and the work adjusted until it sets level on the table. Several trials and adjustments

are usually necessary before the work is correctly set so that all points pass at the same distance from the stick. The jaws *b*, which are supported on extension arms *c*, which in turn are bolted to the table *d*, are used for centering and clamping. The jaws are equipped with adjusting screws *e* to control the grip *f*.

13. When all adjustments have been made, two drivers, one on each side of the work, are set against any available projections. In the illustration, the drivers are the angles *g*.

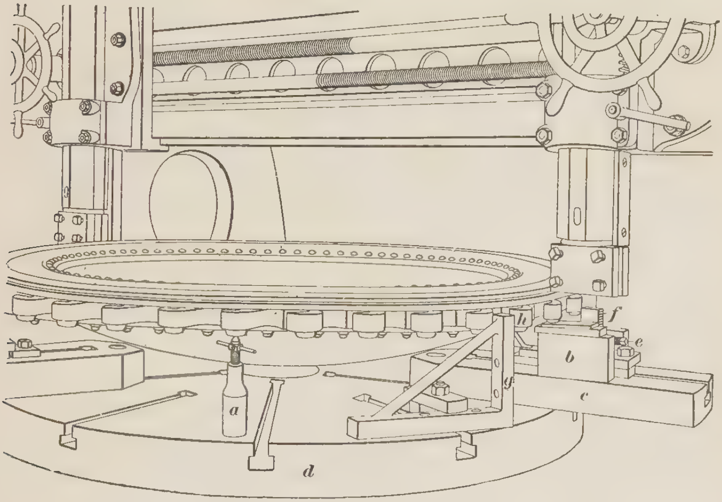


FIG. 4

They are set against the lugs *h* and clamped on the table, as shown. When the piece has been properly secured, it is well to test the setting again, and to look over all bolts, to be sure that every part is fastened securely, after which the machine may be started, the speed properly adjusted, and the tools fed as required. The shape of the tools, and the cutting speeds and feeds are the same as in a similar operation in a lathe.

The piece shown is held by three vertical jacks *a*, three jaws *b*, and two drivers *g*. On pieces where a flange or any

other surface upon which a clamp may secure a hold is available, clamps are used in preference to the jaws, drivers being applied to prevent any sliding on the table. In some cases,

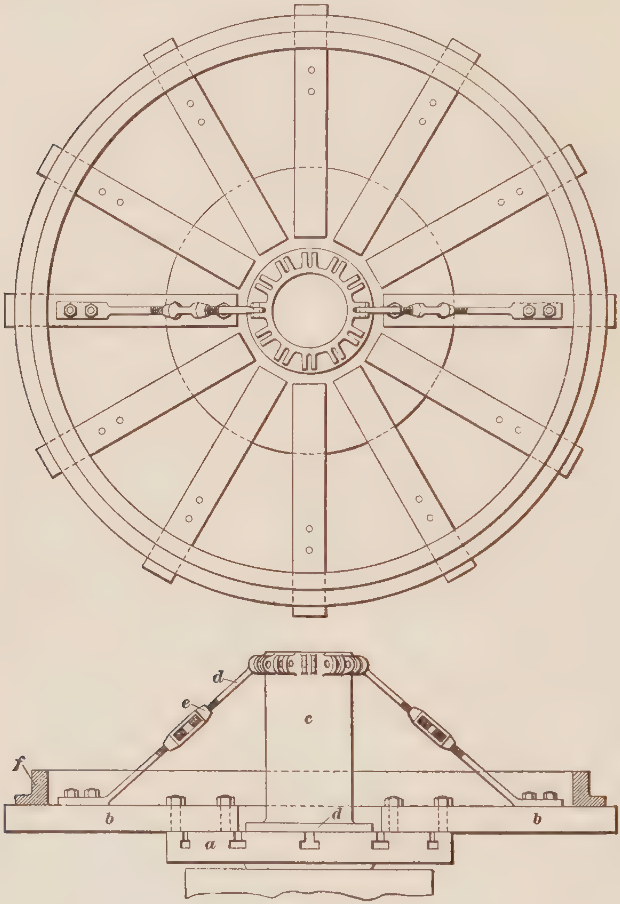


FIG. 5

the weight of the part, together with the clamps, furnishes grip enough on the surface of the table to prevent any slipping, but this grip is very uncertain, and it is better not to depend on it entirely.

14. Extension Arms for Vertical Boring-Mill Table. A boring mill is required at times to turn work that is larger in diameter than the boring-mill table. When this is the case, extension arms like those shown at *c*, Fig. 4 may be used. There are, however, cases where the extension arms must project so far beyond the edge of the table, and where the weight is concentrated so near the end, that additional support is needed to prevent objectionable springing. Fig. 5 suggests a means of providing such support when the center of the piece is open, as in the case shown. The table *a* of the boring mill is of the ordinary type, with radial slots. The extension arms *b* are bolted to the table in the ordinary way. At the center of the table a pillar *c*, with a flanged foot that is bolted to the table, furnishes the upper support for diagonal tie-rods *d* whose lower ends are bolted to the arms, thus forming an additional support. Turnbuckles *e* in the tie-rods permit the arms to be adjusted approximately level, after which a light surface cut may be taken to true them up perfectly. The work *f* is then fastened in any convenient way that its shape will permit, and turned to size.

This is a comparatively inexpensive and efficient shop expedient, which, however, may or may not be a means of economy, depending on the number of pieces for which it can be used and the cost of having the work done in a shop equipped for it. Shop expedients are frequently resorted to when the work could have been done outside more cheaply. Great caution should be exercised in their construction in order that true economy may be practiced.

15. Fixture for Turning Spherical Surface.—A fixture for turning a spherical surface on a vertical boring mill is shown in Fig. 6. The machine has two saddles. One saddle *a* has bolted to it a bracket *c*, which carries a pin *d*, around which swings the link *e*. The saddle *a* is clamped to the cross-rail so that the point *d* lies in a vertical line forming the axis of rotation of the table. The other saddle *b* is detached from the cross-feed screw in the cross-rail, and is free to move crosswise. A bracket *f*, having a roller on each end that bears

on the cross-rail, is attached to the saddle so as to carry its weight, thus reducing the friction and providing a free motion along the rail. The boring bar *g* has an arm *h* attached near its upper end, which carries the fulcrum *i* of the link *e*. The link *e* continues to a point *j*, where a vertical link *k* is hinged. At the lower end, the vertical link *k* is hinged to the lever *l* at *m*.

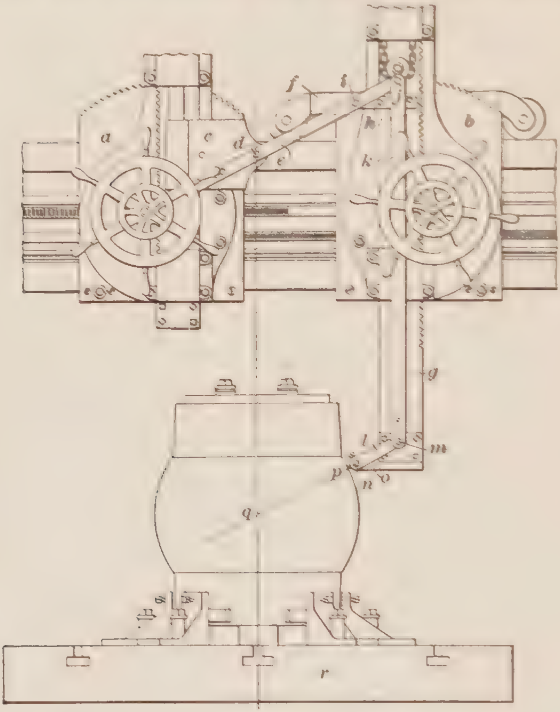


Fig. 6

The lever *l* is pivoted at *n* on an arm *o* attached to the bottom of the boring bar and at its end carries the cutting tool *p*.

16. The piece *q* to be turned is fastened centrally on the table *r* of the boring mill. When the links are properly proportioned the tool will travel in an arc of a circle, and, when the table is rotated and the boring bar is fed vertically, will turn in a true sphere. In order to accomplish this, the length

of the link *k* and the vertical distance between the pivots *i* and *n* must both be equal to the vertical distance between the center of the sphere to be turned and the pivot *d;* the distance *d i* must be equal to the distance from the center of the sphere to the pivot *n*, that is, the sum of the radius of the sphere and the distance of the tool point from its pivot *n*, and the distance *i j* must be equal to the distance *n m*.

17. As the boring bar *g* is fed up, the saddle *b* will be drawn by the lever *e* toward the center of the sphere, when turning the upper half of it. The pin *i* then swings about its center *d*, and the pin *n* travels in an arc of the same radius about the center of the sphere. When in the course of the turning the pin *n* comes as near the table as the center of the sphere and the boring bar is fed downwards, the saddle *b* will again travel toward the center of rotation.

If the distance *d i* is made equal to the sum of the required radius of the sphere and the distance from the tool point to the pivot *n*, the tool will form a perfect sphere of the required radius. The center line of the link *n m* will always point to the center of the sphere. In this work, a narrow, round-nosed tool is used with a comparatively light feed, so as to insure a smooth surface.

HORIZONTAL BORING-MILL WORK

18. Operations on Horizontal Boring Mill.—Horizontal drilling operations are so closely associated with horizontal boring that they will be considered together. Nearly all horizontal boring machines are designed for drilling, boring, and milling, the spindle being designed for any of these operations. As all holes to be bored must be previously drilled or cored, to form an opening through which the boring bar passes, an arrangement permitting the drilling and boring at one setting of the work is economical.

19. Small holes, up to about 2 inches in diameter, are usually drilled, and a machine that will do both the drilling and the boring with one setting saves a large amount of time.

Resetting, or moving to another machine, frequently takes more time and requires a larger number of men than the drilling or boring, and in the meantime the machine is standing idle and the additional service of a power crane is often necessary. For the same reason it is an advantage to be able to perform a milling operation at the same setting. These three operations require practically the same spindle action, and can, therefore, be carried on in the same machine. It is economy to have machine tools so arranged that the greatest possible amount of work may be done with one setting. This should always be borne in mind when selecting and arranging machines, as well as in their operation.

SIMPLE TYPE OF HORIZONTAL BORING MACHINE

20. Horizontal Boring-Machine Head.—One of the simplest types of horizontal boring machines is illustrated in Fig. 7. The general arrangement of the head resembles very closely that of a lathe, the cone pulley and back gears being the same. Instead of the ordinary face plate, there

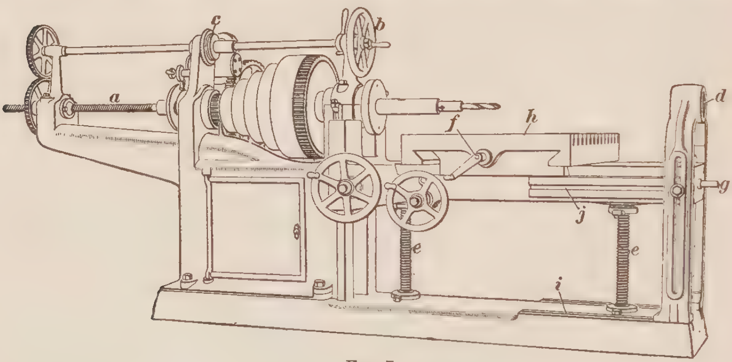


FIG. 7

is an attachment on the end of the spindle for supporting either a drill or a boring bar. The spindle runs through the center of the cone and is so splined that, while it rotates with the driving gear, it may be fed through it by means of the screw *a*, which is turned either by the hand wheel *b* through the shaft and gearing shown or by power through the gearing at *c*.

21. Boring-Bar Support, Table, and Carriage.—An outer bearing *d* forms a support for the outer end of the boring bar. The table is also supported at the outer end and provision is made for vertical, side, and longitudinal adjustment by means of the screws *e*, *f*, and *g*, respectively. The screws *e* control the up-and-down movement of the table, and the screws *f* and *g* the crosswise and lengthwise movement of the cross-table, or **carriage**, *h*. In order to prevent any unnecessary spring in the boring bar, the yoke containing the outer bearing *d* may be moved near the work and clamped in position by bolts that fit in the **T** slots *i* of the base and *j* of the main table of the machine.

22. Boring.—Boring is done on a horizontal boring machine by supporting, independently of the piece to be bored, a bar that carries one or more cutters. The center of the bar thus forms the center of the bored hole independently of the center of the original hole. When the center of the new hole does not correspond with the center of the original hole, the heavy cut on one side will cause the bar to spring and the hole will be neither perfectly round nor straight. One or two light cuts after the roughing cut has been taken usually true it up. When the cut is uneven or when the hole must be bored very accurately, provision should be made for a finishing cut by using a roughing cutter set to bore a hole slightly undersize.

23. Single-End Boring Bars.—Four kinds of boring bars are used in horizontal boring mills, namely, *single-end bars*, *traveling bars*, *bars used on centers*, and *traveling-head bars.*

The holes in the work to be bored sometimes do not pass clear through the part to be bored and are known as *blind holes*. When this is the case it is, of course, impossible to support the boring bar on more than one end. The single-end bar shown in Fig. 8 (*a*) is used to bore blind holes. The shank *a* is tapered to fit the machine spindle and usually has a slot *b* through which a key may be driven to hold the bar in the spindle. The outer end of the bar is slotted, and a cutter *c* is secured in it by the setscrew *d*, which enters a

drilled spot on the cutter. The friction between the shank and socket, the key, and the tang act as drivers. Single-end bars are generally made very short, so that they will be rigid. They are seldom used to remove more than a few inches of metal.

If holes must be bored very accurately, a set of cutters, consisting of one or two roughing cutters and a finishing

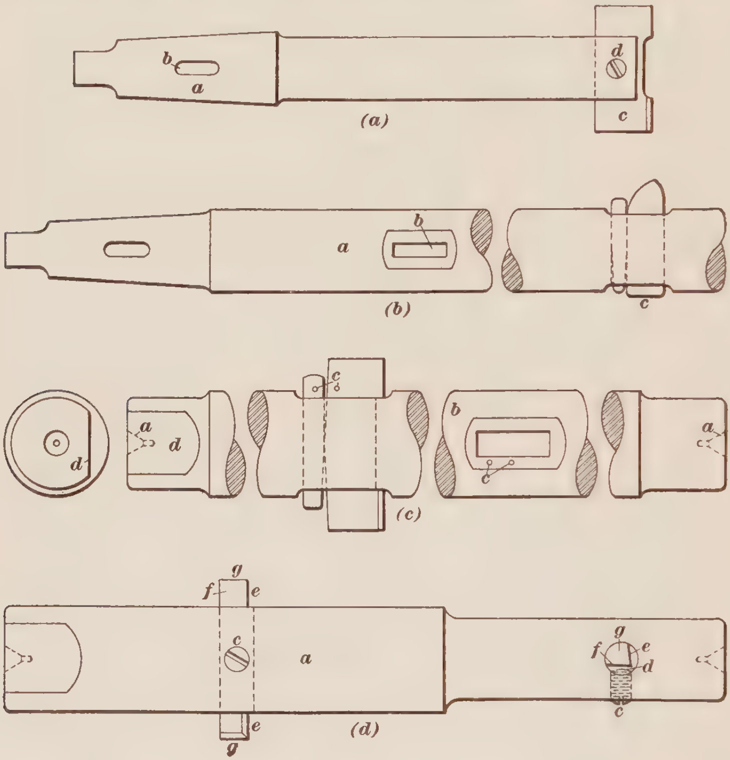


Fig. 8

cutter, is made. These are run through in succession to true and size the hole. If desired, the hole may be bored nearly to size and be finished by reaming. When cutters are made in sets they are always marked for the bar and slot in which they fit and are numbered in the order in which they are to be used.

24. Traveling Boring Bars.—Many of the horizontal boring mills depend for their feed on a spindle fed lengthwise through the head of the mill, and the boring bars used on them are known as traveling boring bars. The traveling boring bar shown in Fig. 8 (*b*) is made with a cylindrical body *a* having a number of slots *b* cut at various points in its length. Single-end and double-end cutters are keyed in the bar, as shown at *c*. When single-end cutters are used, they are adjusted to take a number of light cuts to true the hole. When double-end cutters are used, they are adjusted to cut on both ends. The traveling bar is held in the spindle by the taper shank and driving key and the tang. The outer end of the bar is supported by a closely fitting bushing in an outboard bearing. This bearing is carried on an upright support or in a yoke on the machine. The bar is turned straight, that is, to the same diameter throughout, so that it can feed freely through the supporting bearing, which is adjusted to the same height as the spindle axis, and in line with it.

Boring bars are frequently made with a slot near each end and one in the middle. These bars are usually made a little longer than twice the length of the part they are to bore. When boring with the cutter in the middle slot, the tool will then just clear the hole. The slots near the ends of the bar are used for facing, as there will be less tendency to chatter when the bars are supported close to the cutters.

25. Boring Bars Used on Centers.—When used on some types of boring mills, the boring bar is centered at the ends, as shown at *a* in Fig. 8 (*c*). In operation, it is driven by a lathe dog or a clamp. Single-end cutters held by a key are commonly used in boring bars. The double-end cutter, made to fit the bar, as shown at *b*, is also frequently used. The double-end cutters are trued in the bar by turning. Prick-punch marks *c* are then made on the boring bar, cutter, and key, as shown. When removed and replaced in position, the cutter and key are always inserted so that the prick-punch marks will be located in the same relative positions. A flat *d* is milled on the end of the bar to which the dog, or clamp, is attached.

When a boring bar is much smaller in diameter than the hole to be bored, a casting, known as a cutter head, slightly smaller than the hole is often secured on the middle of the bar. The tool is then secured to the side of the cutter head by clamps and capscrews.

26. A form of special boring bar used to bore two holes of different diameters but located in line is shown in Fig. 8 (*d*). This bar is made to be used on centers but may also be made with a tapered shank. The bar *a* is drilled as shown to receive the cutters, which are made of round tool steel and held in place by setscrews *c* that enter holes spotted in the drill point as shown at *d*. When the cutters are so spotted they will not slip when the setscrews are tightened. The cutters, when set, are turned to the required outside diameter and squared up on the cutting side as shown at *e*. Corresponding marks are then made on the cutters and bar, the cutters are removed, the face *f* is filed flat, and clearance is filed on the faces *e* and *g*.

Boring bars of this kind are generally used when a number of the same kind of pieces are to be bored. The cutters are run through in regular order, the first, or smaller, cutters taking the roughing and truing cuts; and the others, or larger cutters, taking the finishing cuts, which prepare the holes so that they may be finished by reaming. This type of bar could, of course, be made with rectangular slots as shown in Fig. 8 (*c*). In that case, the cutters would be secured in place by keys.

27. Traveling-Head Boring Bar.—The traveling-head boring bar, one form of which is shown in Fig. 9, is one in which the head holding the cutting tool is traversed along the boring bar. It is used to bore holes of comparatively large diameter, and is mounted on centers and driven by a dog or a clamp. A bar of this type is also well adapted to boring work secured to the ways of a lathe. The bar *a* is usually made of cast iron, cored out so as to furnish the greatest stiffness with the least weight. The traveling-head bar is made just enough longer than the length of the holes to be bored so that the boring head *b* will clear either end. The

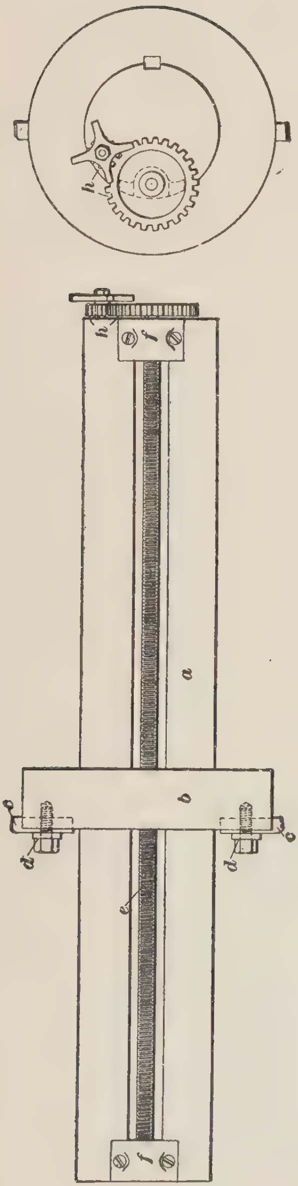


FIG. 9

head b is bored to fit the bar and turned on the outside to a diameter somewhat smaller than the diameter to be bored. One or more boring tools c are let into the head, as shown, and are held in place by the straps and tap bolts at d.

28. The boring head is traversed by means of a screw e, in a slot in the side of the bar, and a nut on the inside of the head. The slot is made large enough so that the nut is free to travel from end to end as the screw is rotated. The head is rotated with the bar by means of a key in the head and a spline that runs the entire length of the bar. The screw is supported at each end by the bearing f and is rotated with reference to the bar by means of a star feed that acts through the gears at h. As the bar revolves, each point of the star comes in contact in turn with a pin secured to a support that is attached to the machine in any convenient way, thus causing the rotation of the star. The movement of the star is transmitted to the boring head through the gears and screw as shown.

If a large boring head is used it is an advantage to use three or four roughing tools at different

points in the circumference for light cuts. Several tools balance each other, and by their use the hole may be roughed out quickly, as the strain on each tool is much less than it would be on a single tool removing the same amount of metal. The finishing should be done with a single tool, as the bar will then spring less, and by taking a number of light cuts with a single tool a true hole will be produced.

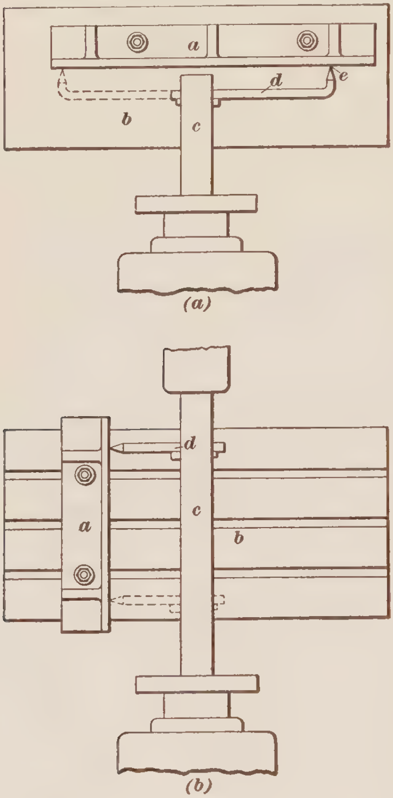


FIG. 10

29. Setting Work and Tools.—The work, which is set on the cross-table, or carriage *h*, Fig. 7, can be drilled and bored in one position, then moved to another position and the operation repeated without resetting. The work is fastened on the table precisely as it is on a drilling machine, and care is taken to have the center line of the hole in perfect line with the center of the spindle.

30. Setting by Tramming.—The work, angle plates or other fixtures may be set square with the spindle by tramming. To do this, the work or fixture *a*, Fig. 10 (*a*), is first set on the table *b* approximately square with the boring bar *c*. A bent bar, rod, or wire *d* is then keyed in the boring bar so that its point *e* will project toward the surface to be squared. This surface and the tram point are then moved toward each other until a feeler such as a slip of paper is held lightly between them. The point of the tram is then moved up and down

over the paper to determine the pressure. The boring bar is now turned half a revolution so that the tram is in the position shown by the dotted lines and the feeler is inserted between the tram point and the work. If the feeler is not held as at first, the work is adjusted according to the indications and another test made on each side. These adjustments and tests are continued until the feeler is held between the tram point and both sides of the surface with the same pressure.

31. Setting by Lining.—The operation of setting the work or the angle plate, or other fixture, parallel to the spindle of the mill is known as lining. An angle plate may be set parallel to the boring bar by adjusting the plate and measuring from the bar *c*, Fig. 10 (*b*), to the face of the angle plate *a*. One way to line the plate is to key a pointer *d* in the bar and move the table so that the end of the pointer will just come in contact with face of the plate as the bar is rotated back and forth. The pointer is then moved to the other end of the angle plate, as indicated by the dotted lines, by shifting the table *b* or by moving the spindle or bar endwise. The test is then repeated and the angle plate adjusted until the pointer touches the face with the same pressure at both ends. A feeler is best for testing the degree of contact between the pointer and the angle plate.

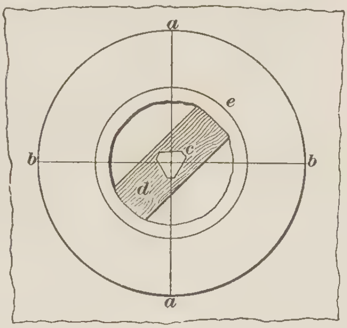


FIG. 11

32. Setting to Layout.—Work requiring one or more holes bored in it is laid out by drawing intersecting lines as *a a* and *b b*, Fig. 11, to locate the center of the hole or holes. The centers are located on the surface, if the stock is solid; but if it is cored the center is located on a triangular piece of tin *c* bent down at the corners and driven into a strip of wood *d* previously driven in the cored opening. The surface

of the work is then chalked and from the center of the required hole a circle *e*, whose diameter is equal to that of the finished hole, is drawn on it.

The work is next secured against an angle plate or a parallel and the boring bar is put in position after the holes have been rough drilled, if not cored. The final adjustment is then made by securing a bent pointer *f*, Fig. 12, in the boring bar and bringing it nearly in contact with the surface of the work. The bar is slowly revolved and the distance the pointer is from the circle at various points is noted. Adjustments both vertical and horizontal are now made until the pointer follows

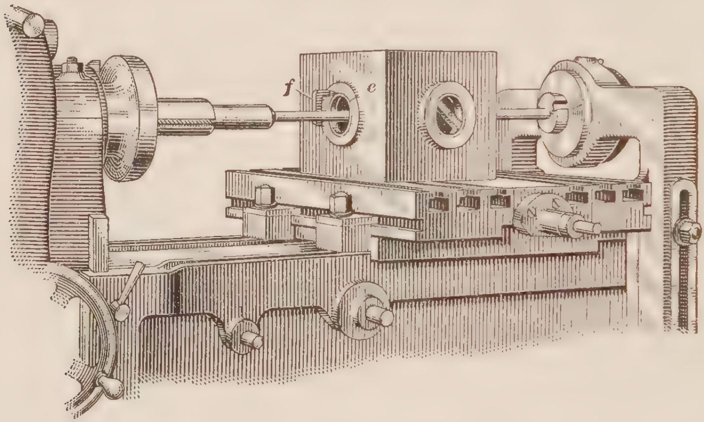


FIG. 12

the circle exactly. The pointer is then replaced by a cutter and the hole is bored, taking several cuts. It is well when near the finished size to note whether the bored hole is true with the circle. If it is not, a slight adjustment of the work may be necessary so the hole will be true with the circle.

33. Example of Vertical and Horizontal Adjustments.—It is frequently required to bore a group of holes at certain fixed distances from each other and from a center line. An example of boring work of this nature is shown in Fig. 13. Here, the work is set up to bore the top hole. The circles locating the holes are first laid out in the usual

way. The top hole *a*, in this case, is bored first and the table is then raised the required amount to bore the lower holes, all the backlash in the elevating mechanism being taken up. If, however, the boring head were adjustable vertically, the lower holes would be bored first and the head would then be raised to bore the other holes. In this way, the backlash would be taken up.

34. When the top hole *a* is to be bored first, the work is lowered so that the center of the top hole is slightly below the center of the boring bar and then raised so that the height of the hole is the same as the measured or gauged distance

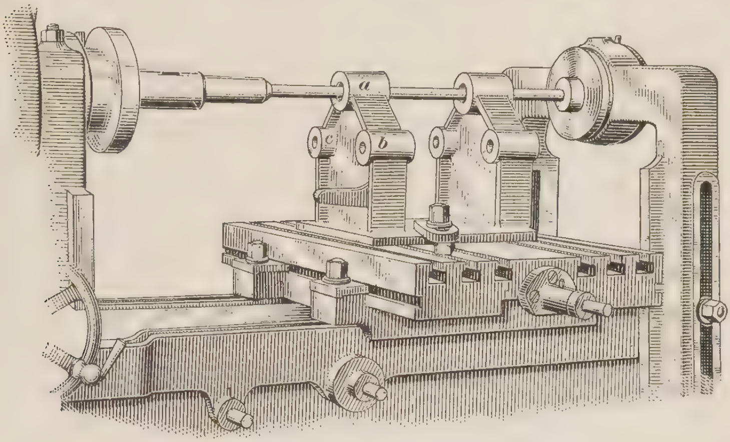


Fig. 13

of the boring-bar center above the table. The table is next fed crosswise to bring the bar central with the boring circle, and the hole is bored to size. The bar is then removed and the table raised the exact distance that the lower holes are to be below the upper ones. The cross-table is then fed crosswise the required distance, and, by taking up the backlash, adjusted to bore the hole *b*. After gauging and checking the distance the table is moved, the hole *b* is bored to size.

The example in Fig. 13 shows another hole *c* on the other side of the center line. The setting for it may be made by feeding the table slightly beyond where it stood to bore the

hole *b* and bringing it back to take up the backlash. The cross-table is then adjusted so that the cutter will just scrape in the hole *b*, after which the bar is removed and the table fed crosswise, the required center-to-center distance from the hole *b* to the hole *c*. To facilitate the adjustment of the boring-mill carriage, stops are often bolted to the side of it and the distances between them and the saddle are measured. If the cross-feed screw has a graduated dial, this adjustment may be made with it and checked by measuring or gauging. The hole is then bored and reamed. If there are other holes or groups of holes they are located and bored in a like manner.

35. Milling on Boring Mill.—The milling done in horizontal boring machines is similar to that done in the heavier types of milling machines. Solid cutters are used for the smaller work, and large inserted-tooth cutters, resembling the heads used on rotary planers, are usually employed in facing large surfaces. The horizontal boring machine is especially well adapted for facing irregular surfaces, the horizontal and vertical feeds being so arranged that either one or both may be thrown in at the same time, thus permitting any path within the range of the machine to be followed. The inserted-cutter end mill is probably the most used for milling on the boring mill, though other work such as dovetailing and **T** slotting are often done. The **T** slots are roughed out to the required depth with plain end mills and finished with regular **T**-slot cutters.

The single-end bar shown in Fig. 8 (*a*) is often used for dovetailing or undercutting, suitable inserted-tooth cutters being used.

HORIZONTAL FLOOR MILLS

36. Example of Horizontal Floor Mill.—A type of horizontal boring, drilling, and milling machine, known as a horizontal floor mill, that is used quite extensively in shops doing heavy work is illustrated in Fig. 14. The boring bar *a* and feed mechanism are carried in a head *b*, supported on a column *c*, which, in turn, rests on the bed *d*. The power is

transmitted to the machine through the cone pulley and back gear at e, and is carried by means of shafting and gears to the boring bar. The machine is so constructed that the head may

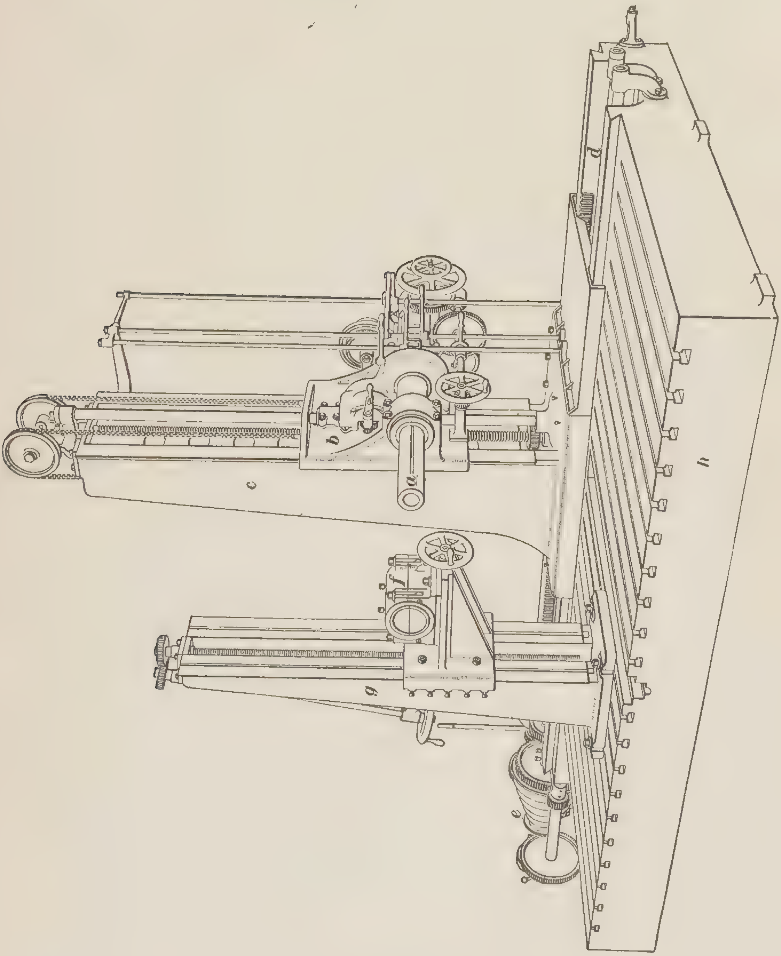


Fig. 14

be moved vertically on the column, and the column horizontally on the bed, while the boring bar moves in and out through the head.

The work is set on a floor plate *h*, which is provided with **T** slots, as shown. The outer end of the boring bar is supported in a bearing *f* mounted on the column *g*, which rests on the floor. The column and bearing may be moved to any location on the floor plate and adjusted to any desired height.

37. The floor plate of this type of machine is sometimes made very large, so as to accommodate very large work or more than one machine. A good arrangement consists of two machines set at right angles to each other, the one being of a heavy class designed principally for boring large diameters, while the other is somewhat lighter and is especially adapted for drilling and small boring operations.

38. Setting and Fastening Work.—The same principles used in securing the work on the tables of planers and vertical boring mills apply to horizontal boring mills as well. It is necessary to set the work perfectly level, and to line up the center line of the proposed hole with the center line of the boring bar. Parallels and blocks, or wedges, are used to raise the work a suitable height, and to level it up. Care should be taken to set the work so it cannot be sprung, and, when properly set, clamps are applied, as shown in Fig. 15.

39. Fig. 15 represents an engine bed set on a large floor plate and being operated on by a traveling-head boring bar driven by a large horizontal boring machine. The bed *a* is mounted on parallels *b*, near each end of the bed, which are clamped to the floor plate by means of the clamp *c*, and the bed is clamped to the parallels with the clamps *d*. A pair of pipe jacks *e*, running out from the corners, as shown, guards against both side and end motion. A duplicate set of parallels, clamps, and jacks, at the other end, which is not shown, holds the bed rigidly in place.

40. Arrangement of Boring Bar, Cutter, and Facing Head.—The illustration shows the boring bar *f*, the boring head *g* with two tools *h* in position, the traversing screw *i*, the outer bearing *j* with the front of its supporting column *k*, the facing head *l* with the tool *m* clamped on the tool slide *n*,

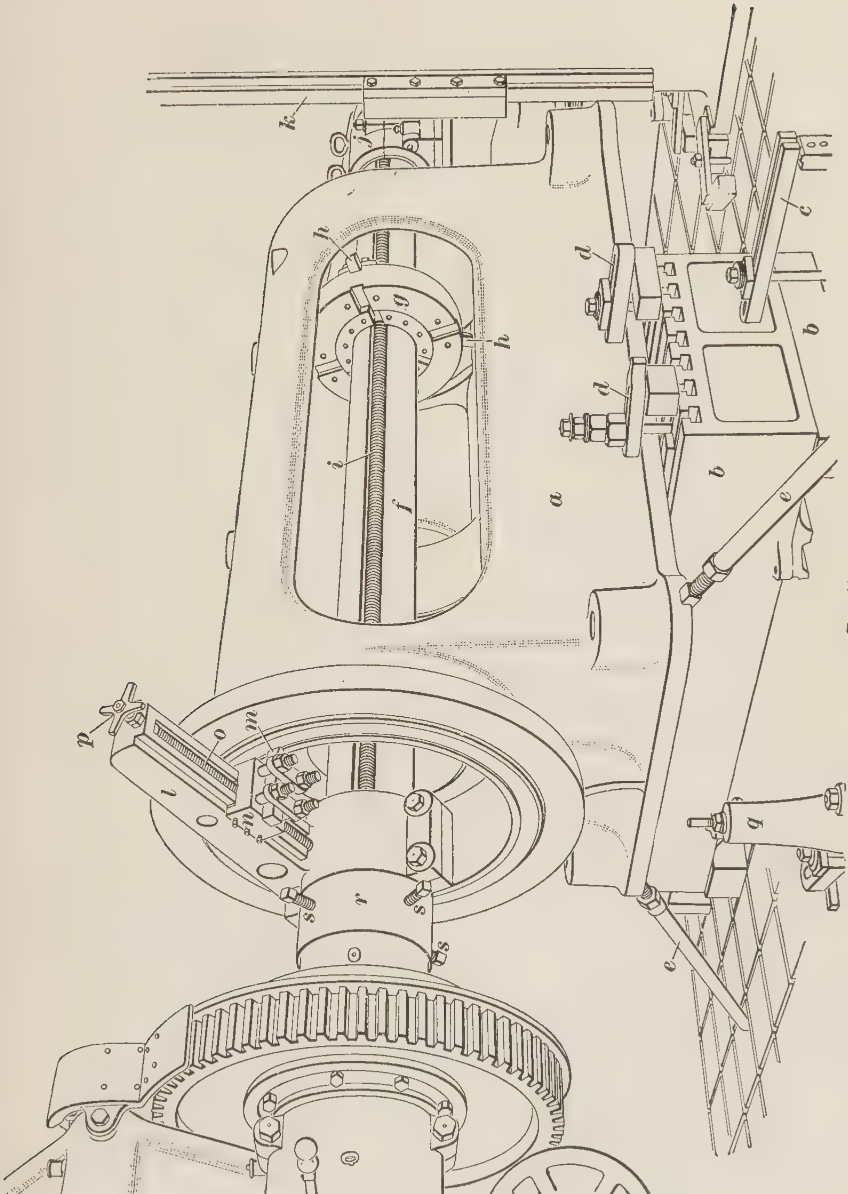


Fig. 15

the feed-screw *o*, the star *p*, and the star feed-post *q*, the last being bolted to the floor plate.

The boring bar is connected to the spindle by means of a special socket *r*. One end of the socket fits the spindle and the other end is bored out to receive the boring bar, which is gripped and held central by means of four setscrews *s*. The illustration shows a typical piece of work for this class of machine, and the usual method of supporting and holding it.

The work is faced true with the bore by the facing head, which is secured to the bar after the boring is done. The body of the facing head *l*, Fig. 15, can be attached to the boring bar at either end of the work by means of the cap and bolts shown, and the cutting tool will feed in or out, depending on whether the feed-post *q* is clamped on the right- or the left-hand side of the bar.

CYLINDER BORING

41. Setting Cylinders for Boring.—Engine, pump, or other cylinders in which a reciprocating piston must operate should always be bored in the position in which they are to be used. The cylinder of a vertical engine should be bored standing on its end, while the cylinder of a horizontal engine should be bored in a horizontal position. In large cylinders, especially, there is considerable spring due to their weight, which will tend to produce an oval shape when a cylinder that has been bored in a vertical position is laid on its side, or when a cylinder bored in a horizontal position is set on end. When the boring is done in its working position, this error is practically prevented.

42. Finishing Cut.—The working surface of the cylinder should be very carefully bored so that it will be cylindrical. There is some difference of opinion as to the best course to pursue to attain this end. Some persons claim that the finishing cut should be taken with a square-nosed tool so that the surface will be perfectly smooth; others prefer a rounded diamond point, the claim being made that the narrow point

is less affected by unevenness in the structure of the metal, and that the slight ridges formed tend to reduce the amount of metal in actual contact, and are an advantage rather than a detriment. The slight ridges also tend to draw the oil under the piston, thus affording better lubricating conditions.

43. All shopmen agree that, whatever tool is used for the finishing cut, it should run continuously from one end of the cylinder to the other. The heating due to the action of the tool causes enough expansion that even a short stop will leave a noticeable ridge, and long stops make it necessary to bore the whole length over again. For this reason, cylinder-boring machines should be run by an independent engine or other motor.

44. Machines Employed in Cylinder Boring.—Cylinders are bored in lathes, vertical and horizontal boring mills, or special machines built for that purpose, depending on the amount of this class of work to be done. Except in shops where enough similar cylinders are bored to require one or more special boring mills, either an ordinary vertical or horizontal boring mill or a lathe is used.

45. Corliss Engine Cylinder-Boring Machine.—A machine for boring large Corliss engine cylinders is shown in Fig. 16. Two adjustable boring bars *a* and *b*, standing at right angles to the main spindle *c*, are provided for boring the ports, while the main spindle *c* bores the cylinder proper. An outboard bearing *d* for the main boring bar, which is mounted on a vertical slide on the column *e*, is raised and lowered by means of the wheel *f* to suit the spindle. The main spindle is driven through the cone and back gear at *g*, while the main head *h* is raised and lowered by a belt that runs on the pulleys *i* and moves the head with a vertical shaft through a worm and worm-gear at *j*. The small heads and boring bars *a* and *b* are operated through the cone and gearing at *k* and shafting and gears in the bed *l* and column *m*. The column *n*, with its bearings, forms an outer support for the two boring bars *a* and *b*. The cylinder is supported on the parallels *o* and *p*.

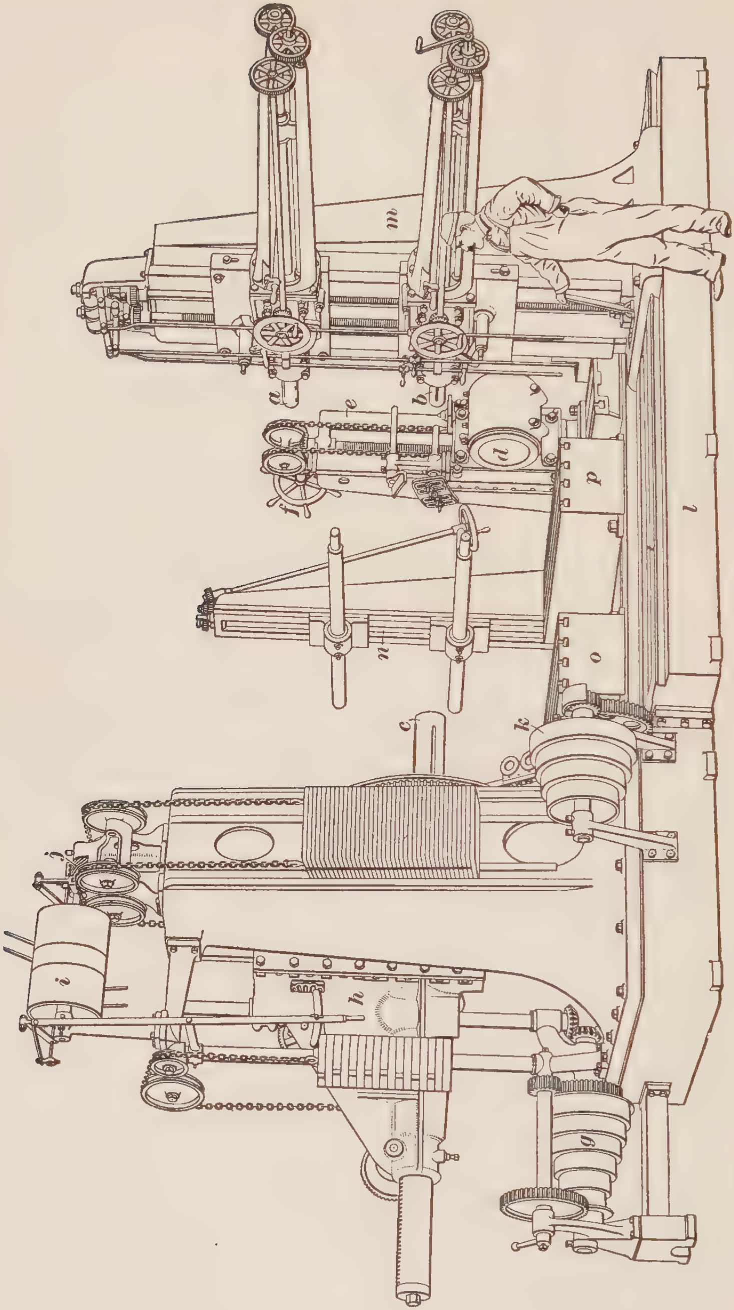


FIG. 16

46. Vertical Cylinder-Boring Machine.—In shops having a large amount of vertical cylinder boring to be done, special machines are sometimes employed; these machines are so constructed that the cylinder stands on a heavy floor plate, to which it is clamped. The boring is done by a vertical bar, the upper end of which, together with the driving mechanism, is carried by heavy columns. These machines are sometimes so constructed that the bar and a portion of the driving mechanism may be lifted out of the way while the cylinder is being placed in the machine. Such heavy machines are usually run by an independent engine or other motor.

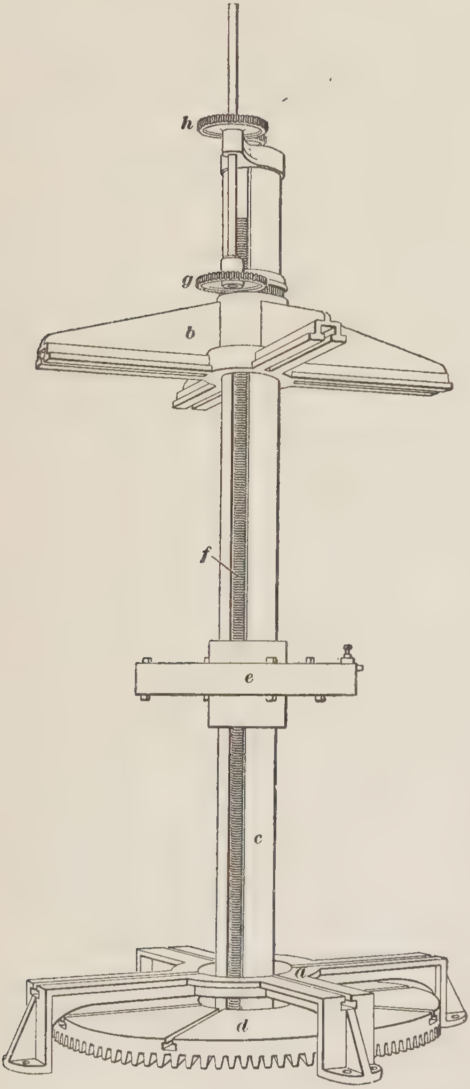


Fig. 17

47. Vertical Cylinder-Boring Bar. In shops where the work does not warrant the purchase of an expensive machine, a vertical boring bar, like the one shown in Fig. 17, may be

used. The cylinder is supported on the stand *a*, and is clamped between it and the four-arm bracket *b* at the top, which also forms the guide for the boring bar *c*. The bar is rotated by a large bevel gear *d* and a bevel pinion driven by a shaft and pulley from which the machine receives its power. The cutter head *e* is fed by means of the ordinary feed-screw *f* and the reduction gearing *g* and *h* shown at the top of the bar.

BORING SPHERICAL BEARINGS

48. Boring Bar for Spherical Surfaces.—Fig. 18 illustrates a device used to bore internal spherical surfaces. It consists of a boring bar *a* having a double-end arm *b* pivoted on the axis *c*, which stands at right angles to the center line

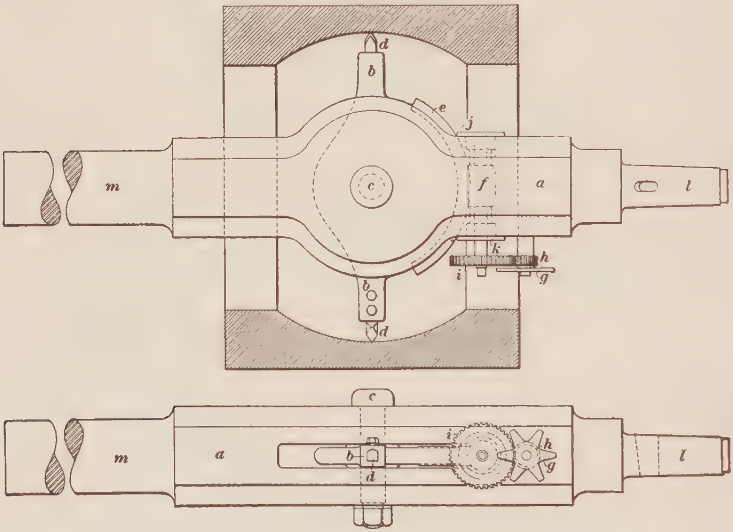


Fig. 18

of the bar. The arm *b* carries on its outer ends two tools *d*, set in and clamped as shown.

If the arm *b* is turned about its axis *c* while the bar *a* is rotating, the tool points will bore an internal spherical surface. In order to secure this motion, the arm *b* is constructed with

the segment *e* of a worm-gear on one side. A worm *f* engages with this worm-gear, so that when the worm is rotated, the arm swings about the center *c*, causing the tool points to travel in an arc about the same center. The worm *f* is revolved by a star *g* through the gears *h* and *i*. A post on the floor operates the star in the usual way. The worm *f* is supported in two flanged bushings *j* and *k*, while the arm *b* is pivoted on a through bolt. The end *l* of the boring bar is made to fit the spindle of a large horizontal boring mill in which it is used, while the end *m* fits the outer bearing. Narrow round-nosed tools are usually employed with a fine feed, so as to form a smooth surface. For the roughing cuts, the two tools may be used, but for the finishing cut. it is best to use one tool only.

49. Portable Device for Boring Spherical Surfaces. When the amount of spherical boring to be done does not

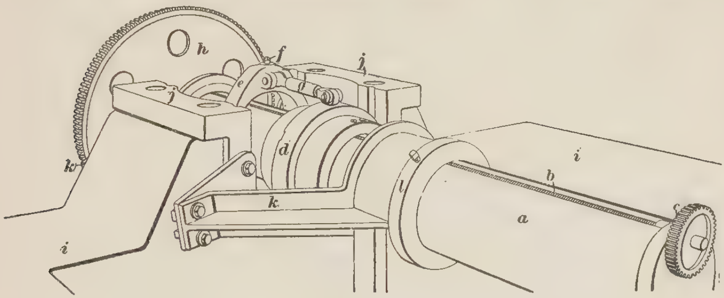


FIG. 19

warrant the construction of a bar as illustrated in Fig. 18, or in cases where a portable arrangement is necessary, a boring bar may be fitted up as shown in Fig. 19. An ordinary boring bar *a*, with its feed-screw and gearing *b* and *c*, and boring head *d*, is fitted up with a forked arm *e*, which is pivoted on both sides of the bar, so that the axis of rotation of the arm and the center line of the bar intersect at right angles. The arm *e* carries a tool *f* and is connected with the head *d* by the link *g*. The boring bar is rotated by means of the worm-gear *h* and a worm and pulley that are not shown. As the screw *b* is

rotated, the head d is moved along the bar, and the link g causes the arm e to swing about its axis, and, when both bar and screw are rotated, the tool will form the desired spherical surface.

The illustration shows the bar mounted on a large engine bed i, ready to bore the spherical bearing j. The bar is supported on two brackets k bolted to the ends of the bearings, and is kept from moving endwise by means of the worm-gear h on one end and the collar l on the other end.

BORING FIXTURES

50. Fixture for Boring Duplex Pump Cylinders. Fig. 20 shows a fixture for holding a set of four pump cylinders while they are being bored in a double-head machine, which

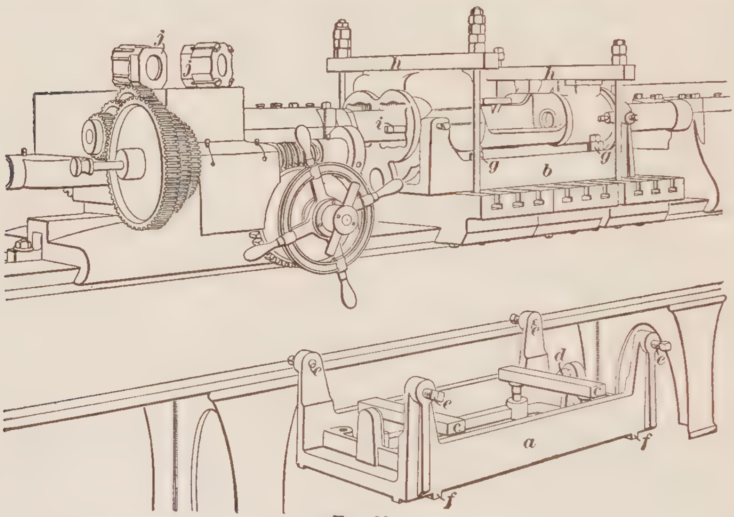


FIG. 20

is also double-ended, the four cylinders being bored at the same time. The cutters at the two ends of the machine rotate in opposite directions, thus lessening the tendency to move. In Fig. 20, a shows the device empty, while b shows a pair of cylinders mounted in the machine. The cylinders rest on a pair of cross-bars c supported on four adjusting

screws. The end adjustment is made by means of a screw *d* at each end, only one of which is seen, while the side adjustment is made by means of the four screws *e*.

51. The fixture is set on the table, as shown, the two tongues *f*, Fig. 20, fitting into corresponding slots, to prevent any slipping and to insure perfect alinement on the table. The fixture is clamped on the table by means of the bolts *g*. When the cylinders are in place and the adjusting screws are set up tightly the cylinders are held securely by means of the clamps *h*. The illustration shows a roughing cutter *i* just entering the cylinder and a pair of finishing cutters *j* lying on the top of the machine.

52. Special Boring Fixture.—Fig. 21 illustrates a special fixture that may be used on either a boring mill or a lathe, for boring the connecting-rod pin hole of a gas-engine piston. The piston *a* is held between the two **V**-shaped castings *b* and *c*. The casting *c* is bolted firmly against the side of the rest as shown, and the casting *b* is loose. The piston

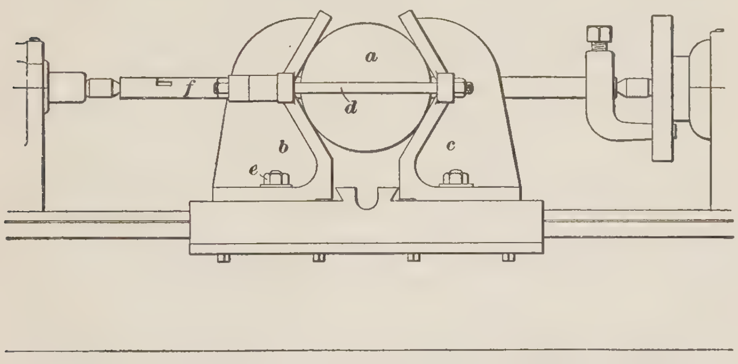


Fig. 21

is placed between the **V**'s, and, when set in its correct position, *b* is drawn up against it by the two end bolts *d*, and the clamping bolts *e* are tightened. In the illustration only one of the bolts *d* and *e* are seen, the others being located in the rear. The boring bar *f* is then passed through the **V**'s and the piston, and the holes are bored in the usual way.

This arrangement insures a hole that is perfectly central and square with the piston. For larger pistons, a single **V** is used in a larger machine, the piston being simply clamped against it.

53. Boring on Drill Press or Radial Drill.—Light boring work that is ordinarily done on a boring mill or lathe may be done on a drill press or radial drill when a suitable jig is provided to support the ends of the boring bar.

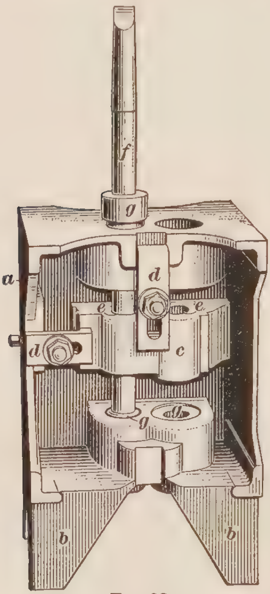


Fig. 22

A good example of a boring jig that may be used on a drill press is shown in Fig. 22. The jig is of the box type and the body *a* is supported by the four feet *b*. The work *c* to be bored is secured to the jig body by means of the two clamps *d*. Two cored holes *e* are to be bored. The boring bar *f* is guided by hardened steel bushings *g* in the upper and lower ends of the jig. The machining operation is as follows: The work is clamped in position against the stops and the boring bar is inserted and fastened in the spindle; one or more double-end cutters are then fed through the cored holes, after which the hole may be reamed with a finishing reamer. The same process is repeated for the other hole.

54. Hand-Power Boring Fixture.—It is frequently necessary to bore or true holes in work that it is impossible to put in a boring mill. This occurs when no boring mill is available, or when a machine bearing gets cut and the expense of taking the injured part out would be too great; it occurs also in repair work, when the boring must be done away from a shop.

A satisfactory hole may be bored by making or selecting a suitable boring bar and providing two bearings in which

the bar is an easy sliding fit. The bearings are then mounted in line with the hole to be bored. The bar is now passed through the work and the bearings carefully leveled and squared so that the hole to be bored will be in the required position. The adjustment of the bar requires skill and judgment. The bar must usually be so adjusted that the hole will have a fixed relation to the other parts of the machine.

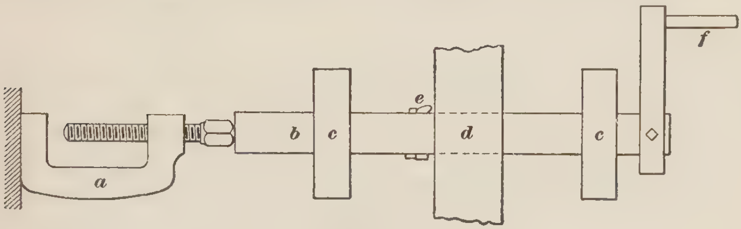


FIG. 23

It is sometimes necessary to take down adjoining parts to uncover flat surfaces or to clear holes from which the boring bar may be located by tramming or lining. A screw clamp *a*, Fig. 23, may be secured so that its screw can be used to feed the bar *b* through the bearings *c* and the work *d*. A cutter *e* is held in the bar, which is rotated by turning the crank *f* by hand.

WORKING CHILLED IRON

CHILLED IRON

1. **Chilled iron** is cast iron that has been chilled, or cooled, rapidly as the molten metal is poured into a mold. Chilling is accomplished by using an iron mold instead of a sand mold, as in ordinary molding. This iron mold is called the **chill**, and, like the sand mold, must have the correct form to make the desired casting. Not all forms of castings may be chilled, owing in some cases, to the severe casting and shrinkage stresses, and in other cases to the inability to chill inaccessible parts of the casting.

In Fig. 1 is shown a cross-section of a mold for making a plain, solid, chilled-iron roll with necks and driving ends, the body only being chilled. The mold for the necks and driving ends of the roll is made of sand. In the illustration *a* is the roll, *b* the chill, *c* the riser head, *d* the cope, *e* the reducer, *f* the sand, *g* the drag, *h* the runner spout, *i* the pouring basin, *j* the joints fastened by clamps and wedges, *k* the end plate, and *l* the chilled surface.

2. **Characteristic Features.**—The rapid cooling of the metal which lies against the chill forms a skin or shell of hard iron varying in depth and hardness according to the composition of the metal and the method of manufacture. This rapid cooling of the metal produces a casting with a hard surface having a great resistance to wear.

Chilled iron may readily be distinguished from sand, or gray, iron by the white color of the fracture as opposed to the gray color of ordinary cast iron. The outer, or clear white, layer

is known as the **clear chill.** Where the shell of chilled iron merges into the gray iron will be found a layer of **mottled chill,** which is a mixture of chilled and gray iron. The mottled-chill layer is usually of about the same depth as the clear chill, the remaining part of the casting being gray iron. The layer of clear chill plus the layer of mottled chill is known as the **total chill.**

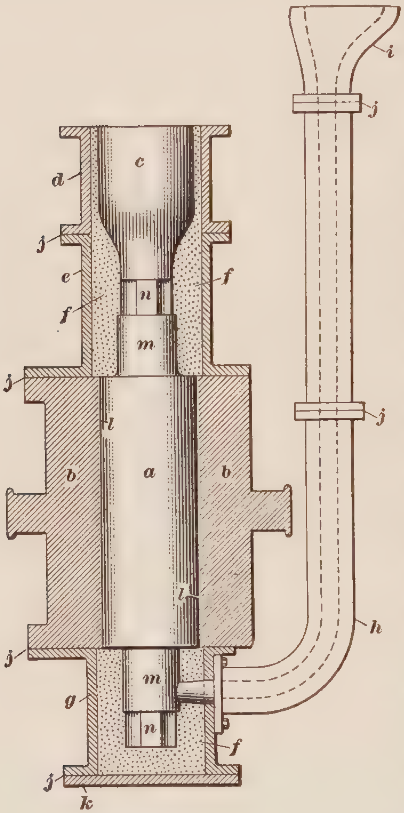


FIG. 1

3. Reading Chill Depth.—When the *chill depth* is spoken of it is understood to mean the depth of clear chill. When reading chill depth, either a clean fracture or a cut taken on the end of the casting at right angles to the chilled surface must be available. The depth of chill can be distinguished readily by the naked eye. In Fig. 2, a section of a casting having a chill depth *a* and a mottled chill *b* is shown.

There are many grades of chilled iron, varying, according to the uses to which they are to be put, from a very mild to a very hard chill. On turning a number of chilled rolls of different grades, it is possible to become familiar with the way they cut; the harder the chill, the more difficult to cut it. When determining the grade of chilled iron in this way, care must be taken to get a good tool, to become familiar with the way it cuts, and to always use tools of the same grade. The degree of hardness of the surface may be readily determined by the

scleroscope. The harder and deeper the chill, the more brittle the casting becomes; consequently, to guard against breakage, the chill should never be harder nor deeper than its use requires.

4. Uses of Chilled Iron.—Owing to its great resistance to wear, chilled iron is used largely for making chilled rolls.

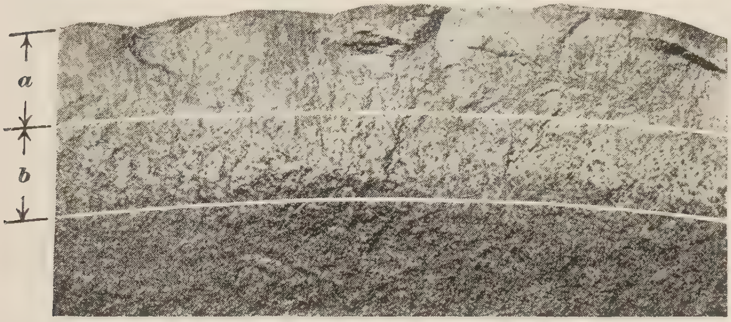


Fig. 2

These rolls are used to roll varied products made from metals, cereals, and other materials. The use of chilled iron is not, however, confined to rolls alone, for the guides for rolling mills, car wheels, rock-crusher plates, dies, anvil blocks, and other articles are made with chilled faces.

MACHINING CHILLED IRON

TURNING AND GRINDING CHILLED ROLLS

5. Essentials.—In working chilled iron, good castings are essential. The castings must be free from cracks, blow holes, and dirt, and the chill must be of the right depth. In turning chilled-iron rolls, special lathes must be employed, and a few general rules must be observed to insure successful work. The cutting speed must be so slow that the tool will hold its edge until it has done a reasonable amount of work. The lathe must have a large amount of power, and the tools and the lathe must be of rigid construction. The tool steel employed must be the best, and selected according to the character of work.

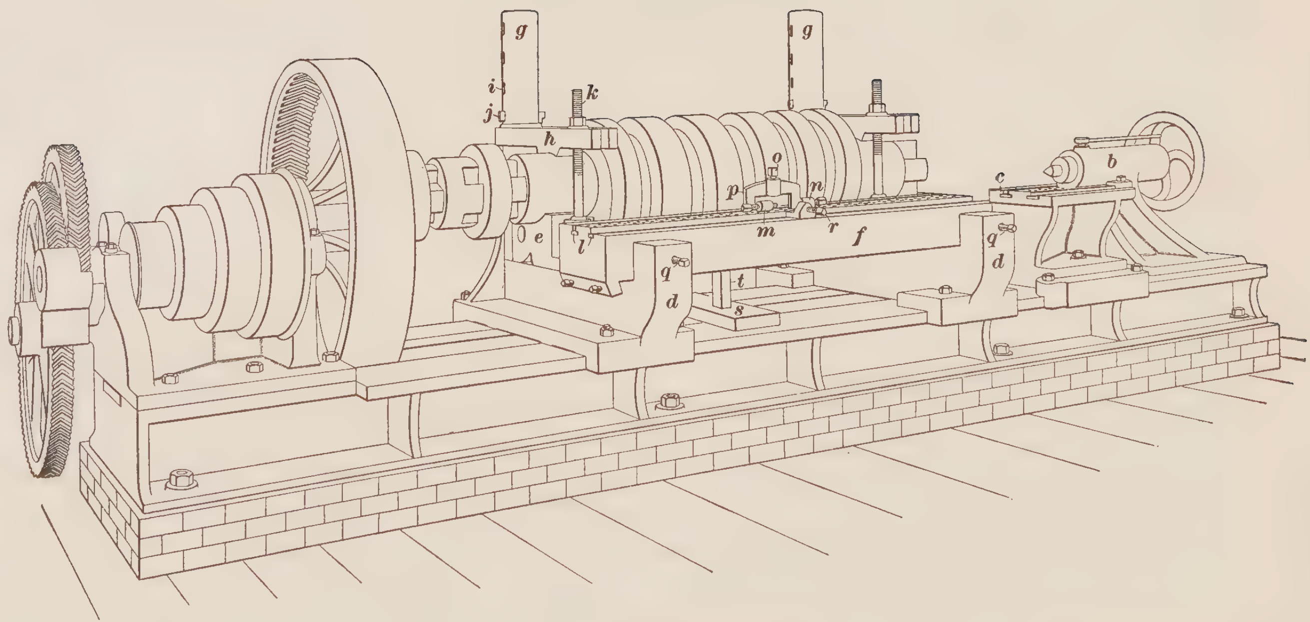


Fig. 3

TURNING SOLID ROLLS

6. Lathes for Turning Chilled Rolls.—A type of lathe for turning rolls cast solid and having journals, or *necks*, as shown at *m*, Fig. 1, and driving ends, or *wabblers*, as shown at *n*, is illustrated in Fig. 3. In common with all lathes used for turning chilled iron, this lathe is powerful and rigid in construction. The bedplate is strongly constructed and is securely bolted to a solid foundation. The headstock is provided with double helical gears, so that the pull may be constant and that the teeth of the gears cannot cause hammering or backlash. Instead of the cone-pulley drive the lathe may have a single pulley with a variable-speed countershaft. This latter practice has the advantage that more speeds are possible. A direct-connected, variable-speed motor may be used to drive the lathe. In Fig. 4 is shown a form of roll lathe in which the machine is driven by a single pulley *a* belt-connected to a variable-speed countershaft.

7. In all cases, chilled rolls are turned by feeding the tool crosswise into the roll, the length of the cutting edge of the tool determining the length of surface turned. Consequently, a chilled-roll lathe is not provided with a feed rod to move the carriage lengthwise. The necks and wabblers being soft, the rolls are frequently centered and necked on an ordinary engine lathe. The operation of turning the necks of rolls is known as **necking.** The riser head may also be cut off in the engine lathe. When the rolls are necked on a roll lathe, the center holes are usually made by hand, using a portable drill to operate the drill and reamer.

The tailstock *b*, Fig. 3, is used when turning rolls between centers, as when necking or cutting off riser heads. On large lathes, the tailstock is provided with rollers which can be raised into position when sliding it along the bedplate. The necking rest *c* is used to support the turning tool when necking. It is moved along the bedplate and bolted in position opposite where it is desired to cut. The roll would then be necked by feeding the tool crosswise.

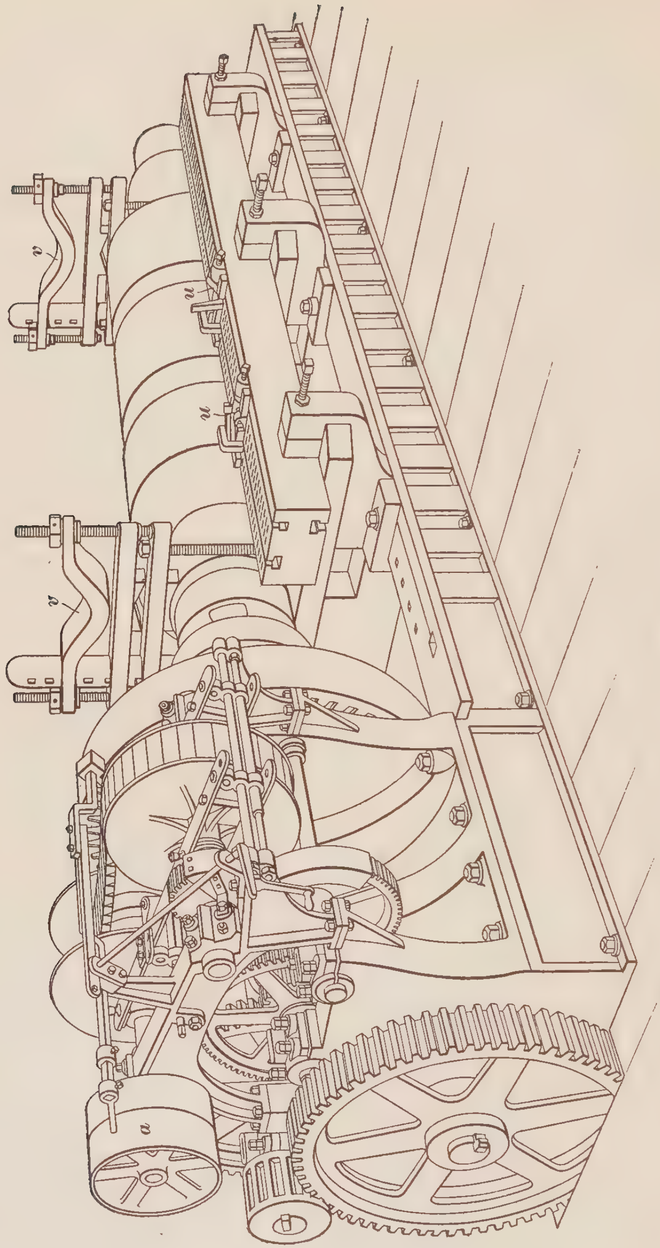


Fig. 4

8. After the rolls have been necked, the tailstock and necking rest are removed and the regular roll-lathe housings *d*, Fig. 3, are placed on and securely bolted to the bedplate. The chucks, or bearing blocks, *e* fit into the housings and form the necessary bearings for the rolls to run in. The tool rest *f*, known as the **piano rest**, is also supported by the housings *d*. The housing posts *g*, which hold the caps *h* in position, and the housings *d* are rigidly connected. The chucks *e* and the caps *h* generally have babbitted faces for the necks to run in. These faces are kept well greased to prevent scoring of the finished necks. In some cases extra bearing blocks are forced between the necks and the housing posts to increase the bearing surface. The caps *h* are made to slip over the housing posts *g* as shown. The housing posts are slotted at intervals as shown at *i* to receive the blocks *j* which prevent the caps from moving upwards. The front end of the caps are held in position by the bolts and nuts *k*. These bolts are keyed to the housings *d*.

9. Material of Tools for Turning Chilled Iron. When working chilled iron, high-speed-steel tools are necessary when heavy and fast cutting is to be done. For this reason, high-speed steel is largely used for roughing tools for chilled iron. As it will not hold a sharp edge, however, it is not adapted to finishing work. High-carbon tool steel hardened in brine does hold a fine accurate cutting edge, and for this reason is chiefly used for finishing tools. It may also be used for roughing work; but this is not advisable if time is an important factor.

10. Solid Turning Tools.—Tools used to work chilled iron are not blocked up from the piano rest, but are made of such depth that, when set up, they will be the desired distance below the center of the work. Clearance on the cutting edge is necessary. A tool set at the center must have a good deal of clearance, making the point weak. A tool set below center can be square, making a stronger cutting edge. Hence, all tools for turning chilled iron, cutting-off tools excepted, are always made and set so that their cutting edges will be below the center of the work. Tools for turning work of large diam-

eter are set farther below center than those used to turn work of small diameter.

11. Different types of tools employed in turning chilled rolls are illustrated in Fig. 5. The **facing tool** used to turn the straight surfaces of chilled rolls is shown in (*a*). It is made from a bar of steel from 1 to $1\frac{1}{2}$ inches square and from 3 to 12 inches long, depending on the work to be done. When making this tool, the stock is first annealed by heating it red hot and cooling it slowly in lime, after which the grooves are formed on a shaper. Each face is now hollow ground, holding the tool parallel with the face of the grinding wheel. The tool is then hardened and touched up slightly on a grindstone, after which the corners are honed to an edge with an oilstone. The **pusher** used to force the tool shown in (*a*) into the roll is shown in (*b*). It may be made of any grade of steel. In use, a copper or brass strip *a* is placed between the facing tool *b* and the pusher *c* to prevent injury to the sharp edges of the tool by the pusher. The pusher must be shaped so that it will bear against the top edge of the tool in order to avoid all tendency to push the bottom part of the tool, to which no resistance is offered, toward the work. If the bottom part of the tool were pushed nearer the work, the clearance angle of the tool would be reduced.

12. One type of **grooving tool** is shown in Fig. 5 (*c*). The exact form of the tool depends on the shape of the groove to be turned in the roll. The tool shown is used to turn flat grooves whose rolling surfaces are parallel and whose sides are perpendicular or nearly so to the length of the roll.

Another type of grooving tool is shown in (*d*). This tool is used to turn diagonal grooves in rolls, as, for example, grooves used to roll squares and diamonds. Both *roughing* and *finishing* tools of this type are used. The roughing tool has a blunt point and is made of high-speed steel. Heavy cutting can be done with this tool. The finishing tool is made of high-carbon tool steel and has a sharp point. To avoid destroying this point, light cuts must, of course, be taken.

13. In Fig. 5 (*e*) and (*f*), forms of roughing tools known as **lip tools** are shown. These tools will remove stock more

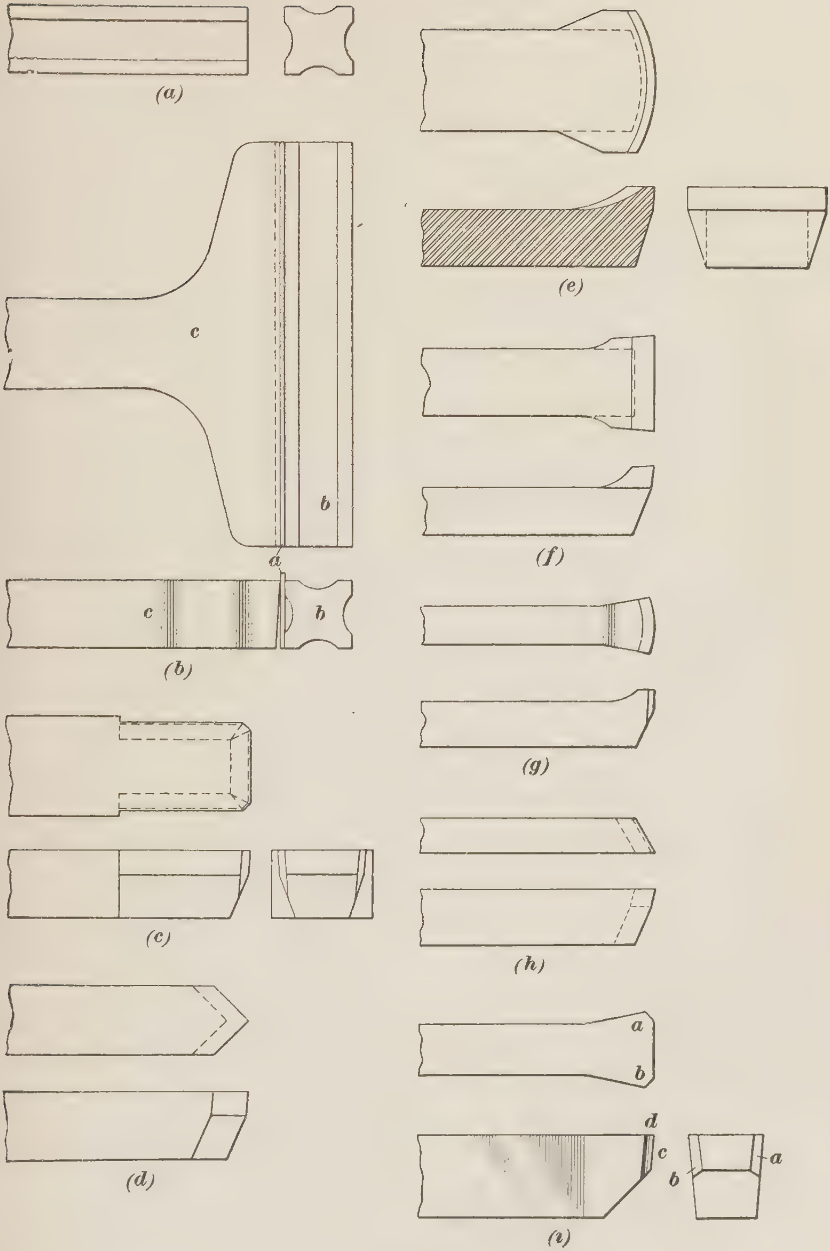


FIG. 5

rapidly than those ground straight on the top. In (*g*) a form of roughing tool similar to that in (*e*), but narrower, is illustrated. It is used to rough out narrow recesses and to cut off riser heads.

In (*h*) the tool for sharpening the corners of the grooves is represented. This tool is employed when cutting off riser heads in the lathe. The tool shown in (*g*) is used first, running the cut down almost to the required depth. Then the tool shown in (*h*) is run in and the corner of the groove next to the roll is sharpened up, so that when the riser head is broken off it will break flush with the end of the roll.

14. One form of **cutting-off tool** is shown in Fig. 5 (*i*). This tool is forged from $\frac{3}{4}'' \times 1\frac{1}{4}''$ steel, and is hardened in brine. The edge of the tool is about $\frac{15}{16}$ inch wide and the corners *a* and *b* are cut off at an angle of about 45°. When the corners are ground to this angle, they are not so easily broken when used as would be the case if left square. The front face of the tool is given a little clearance as shown at *c*. This clearance is seldom more than 5°. This cutting-off tool is used to cut through the chilled iron, an ordinary cutting-off tool being employed to cut through the softer iron at the center of the roll.

15. Cutting-off tools must overhang the front edge of the tool rest to a greater extent than the turning tools. They are therefore made deeper from the top to the bottom, and consequently stronger. In use, the top face *d* of the tool shown in Fig. 5 (*i*) is set above the center of the roll, and clearance must be allowed on the face *c* as shown. When it is necessary to have a tool overhanging the front edge of the tool rest, the tool prop *t*, Fig. 3, and the bar *s* that support it are used. The tool prop is made just the right length and is placed under the front edge of the tool. This relieves the stress on the tool, making it possible to use lighter tools.

16. It was formerly considered good practice and economy when making wide tools to use tool steel for the cutting edge only and weld the tool steel to a shank made of machinery steel. However, it takes time to make the weld and the tools are often lost by cracking in tempering. Tools made of solid tool steel

can always be used or changed to other shapes, where the welded tool would have to be scrapped. For these reasons, modern practice favors the use of solid rather than welded tools.

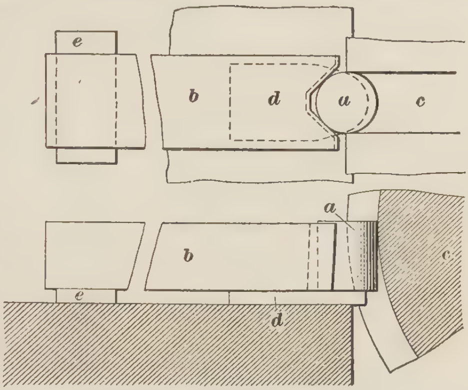


FIG. 6

17. A tool for turning small round and oval grooves is shown in Fig. 6. The tool *a*, called a **plug,** is a cylindrical piece of tool steel with both ends squared and ground. The **push-up** *b* is used to force the cutting edge into the roll *c*. The tool is supported on the blocks *d* and *e*, which are of such thickness that the cutting edge of the tool will come about $\frac{1}{8}$ inch below the center of the roll. Any portion of either the top or bottom end of the plug may be used to cut the groove. In case both ends are dull, the plug may be resharpened by grinding its ends. The block *d* forms a rest for the plug; prevents the tool from digging in, thus marking the main rest; and also prevents the tool from tipping over when the grooves are turned deep. The push-up is made with clearance so that it will bear against the top of the plug as in the case of the facing tool.

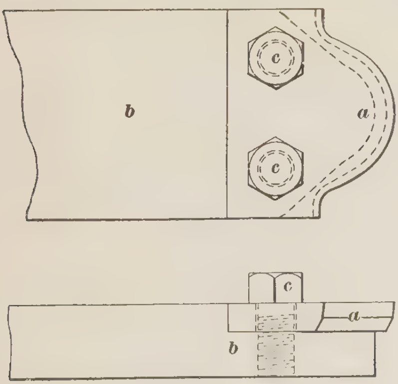


FIG. 7

18. Built-Up Turning Tools.—In Fig. 7 a built-up tool for turning large grooves is shown. The tool is used chiefly to turn circular grooves; but tools are also made

to turn irregularly shaped grooves. The cutting portion *a* of the tool is made of high-speed tool steel for the roughing, and high-carbon tool steel for the finishing operations; the tool block *b* is made from machinery or any other kind of steel available. The tool is fastened to the block by the bolts *c*. This form makes a good substantial tool. The tool block may be used to hold different cutters.

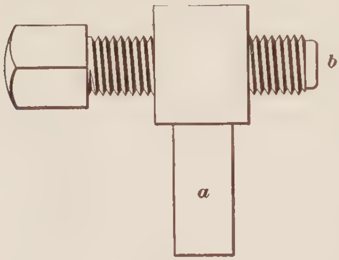


FIG. 8

19. Holding Tools. Owing to the severe stresses to which tools for working chilled iron are subjected, they are not held in an ordinary tool post, but are clamped very rigidly to the tool rest *f*, Fig. 3. This rest is provided with two **T** slots *l* and with rectangular holes in its upper surface, as shown. These rectangular holes are fitted with dogs *m* and *n*. The dog *m*, a larger view of which is shown in Fig. 8, is similar to the ordinary planer plug, and the shank *a* is square or rectangular, depending on the form of the holes in the rest. The end *b* of the setscrew is brought in contact with the tool or the blocking. The dog *n*, Fig. 3, is of the general form shown in Fig. 9, and is arranged to fit into a **T** slot, indicated by the dotted lines. The lug *a* is so formed that the dog can be easily removed from the **T** slot by simply lifting up on the head of the setscrew *b*, and when the end *c* of the setscrew is brought against the work, the lug *a* will take hold of the **T** slot and hold the work firmly in place. The tools are held from behind and at the sides by means of the dogs just described, and are held down by means of the setscrew *o* in the clamp *p* shown in Fig. 3. The tool and rest are advanced toward the roll by turning the screws *q*, and the tool only by turning the screw *r*. The tool is forced into the roll

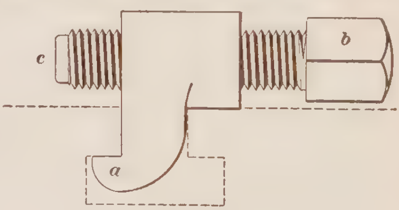


FIG. 9

by turning the screw r. The screws q are used merely to back up the rest, so that when the tool is cutting it will not force the rest back from the face of the roll. It is not necessary to have the rest parallel to the axis of the roll. When cutting deep

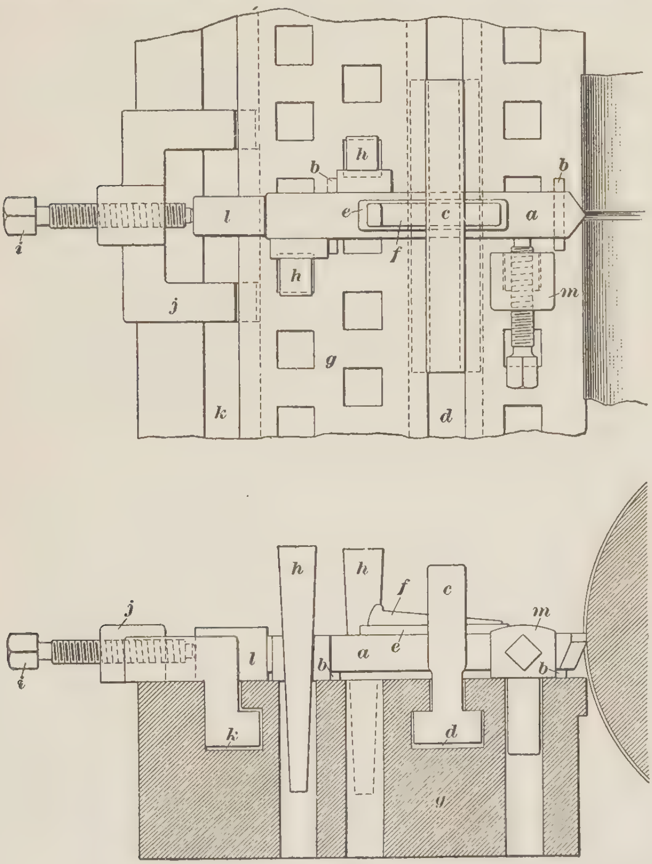


FIG. 10

grooves the tool extends rather far out in front of the tool rest and must be supported. This may be done by the use of a prop bar s, and the prop t, on which the front edge of the tool rests.

20. The device u, Fig. 4, for holding the tool is shown in detail in Fig. 10. The tool a is set on two pieces of packing b

to bring it up to the correct cutting height. The saddle *c*, which works in the **T** slot *d*, together with the block *e* and wedge *f*, keeps the tool forced against the tool rest *g*. The wedges *h* hold the tool at right angles to the work as it is advanced into the roll by the screw *i*, which works in the pusher *j*. This pusher is held in the **L** slot *k* of the rest. The block *l* is placed between the tool and the screw, in case the tool is not long enough to reach to the screw. Screw blocks, as shown at *m*, are sometimes used in place of the wedges *h*.

21. Grinding Turning Tools.—To secure a straight edge on the tool, it is ground on a grinding machine provided with a carriage or special tool holder. The sides of facing tools are ground concave, or hollow, as shown in Fig. 11. In this way two sharp edges *a a* and *b b* are produced. The marks left by the grinding wheel are removed by rubbing an oilstone over the face of the tool. The tool is first set to use one edge as *a a* and when dull, the tool is turned over and the other edge *b b* is used.

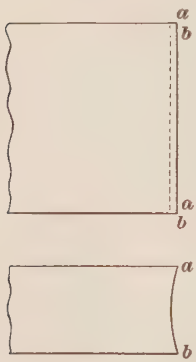


FIG. 11

22. A type of wet grinding machine provided with a carriage and used to sharpen tools for cutting chilled iron is shown in Fig. 12. The machine is fitted with a slide *a* to which the tool is clamped at *b*. The depth of the cut is regulated by the screw *c* and the clearance angle by the screw *d*. The tool is fed back and forth across the face of the grinding wheel by means of the hand wheel *e*, a pinion engaging with the rack *f*, which is secured to the bottom of the slide *a*. With this device, tools may be ground accurately and quickly.

23. Cutting Speeds.—To a great extent the cutting speed depends on the character of the chilled iron being turned and the diameter of the roll. On small rolls a surface speed of from 34 to 36 inches per minute is good practice, while for large rolls a surface speed of from 28 to 30 inches is used. A surface speed of 40 inches per minute is probably as high a

speed as could be employed with good result, although a speed of 11 feet per minute has been obtained on very mild chilled iron. In this case the tool steel used was exceptionally good.

24. Cutting Feeds.—In turning chilled iron, the tool is never fed along the work lengthwise, but at right angles to the face being turned. This feeding is done by hand through the use of a wrench and screws. The amount of feed depends on the hardness of chill being turned, the size of the roll, and the

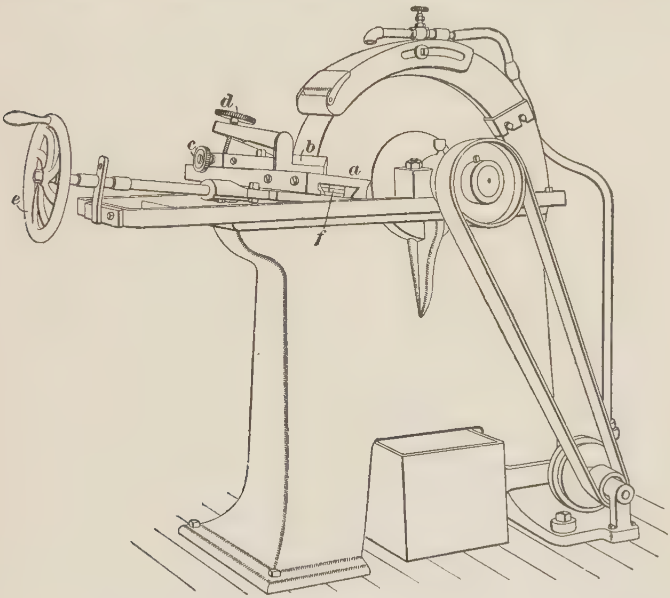


Fig. 12

strength of the lathe and its attachments. On a roll of mild chill and large diameter using a high-speed-steel tool of the form shown in Fig. 5 (*f*) on a very rigid lathe, a cut $\frac{3}{64}$ inch deep may be taken. This is the deepest feed that may be used on chilled iron, and it is not practicable to employ it, as the tools will stand up for a short time only and the wear on the lathe is excessive. Ordinarily a cut of about $\frac{1}{64}$ inch deep is considered a good average cut. In turning a plain chilled roll a tool of the form shown in Fig. 5 (*a*) is used. Cuts .01 inch deep may

be made with this tool. This depth of cut is, however, rather excessive, the normal depth being about .003 or .004 inch.

25. Setting Up Roll in Lathe.—The center holes of chilled rolls include an angle of 60°, and their width across the mouth varies from ½ to 3 inches. For a 500-pound roll, a width of mouth of 1 inch, and for a 2,000-pound roll, a width of mouth of 2 inches, is good practice. As all rolls are cast on end, the bottom, or drag, end is necessarily more solid and true than the top, or cope, end, sometimes called the riser, or head, end. The top face of the riser head is piped considerably and is very rough and irregular, owing to shrinkage, feeding,

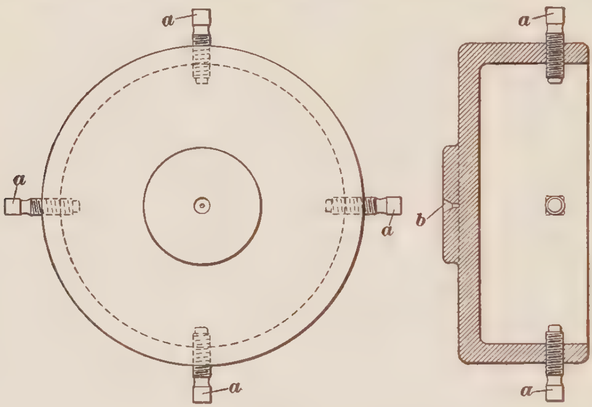


FIG. 13

and dirt. For these reasons, the cope end is not centered, a *false center*, Fig. 13, being attached to it by means of the set-screws *a*. This false center contains a center hole *b* which receives one of the lathe centers. The drag end of the roll is centered as usual, and the roll is put on the lathe centers with the false center on the tailstock end. By adjusting the screws *a*, the work may be adjusted until either the wabblers or the body runs true. The usual practice is to set the large rolls so that the bodies run true, and the small rolls that are to run at a high speed in the mills, so that the wabblers run true. If these fast-running, small rolls were not turned true to the wabblers, the wabblers would probably break off in service.

26. Testing Casting.—Before finishing the roll, it is tested for chill depth, evenness of chill, and flaws. To test for chill depth, take a cut over each end of the roll, using a tool of the form shown in Fig. 5 (*f*), and observe the depth of chill as explained in Art. **3**. The drag end usually has a deeper chill than the cope end. The evenness of chill may then be discerned by following the line of clear chill around the body. When in cooling and shrinking the roll leans to one side of the chill, the depth of chill on that side will be the greater, the opposite side having a shallow chill depth. If this condition is very marked, the roll is made unfit for use. A few cuts are taken on the surface of the body of the roll, using a tool of the form shown in Fig. 5 (*f*), to determine whether it will true up without flaws.

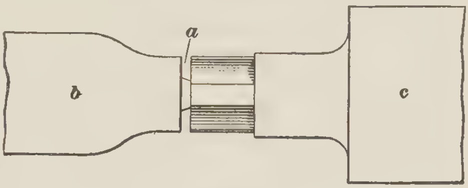


FIG. 14

27. Cutting Off Riser Head and Necking.—If, by testing, the roll has been found to be satisfactory in all respects, the riser head is cut off. This may be done by using a round-nosed lip tool like that illustrated in Fig. 5 (*g*), cutting into the roll as shown at *a*, Fig. 14, the tool being secured to the necking rest *c*, Fig. 3. A deep groove is made, the corner being sharpened with a tool of the type shown in Fig. 5 (*h*). The roll is then removed from the lathe and the riser head *b*, Fig. 14, is separated from the body *c* by means of wedges and a few blows with a sledge. The cope end of the roll is now centered, and the roll is put on the lathe centers and necked—that is, the journals are trued up. The necks are now turned to size unless they are to be ground and polished. In this case a little stock is left. As this part of the roll is not chilled, the lathe is run at the regular gray-iron speed except when cutting near the body where chill will be found.

28. Turning Body of Plain Roll.—After necking, the roll is removed from the centers, the tailstock and necking rest are taken from the lathe, and the housings *d*, Fig. 3, are set

up in place. The roll is caused to turn in the bearings *e* by the driver *a*, Fig. 15 (*a*) An end view of the driver is shown in Fig. 15 (*b*). The driver fits over the spindle *b*. This spindle is shaped like the wabbler *c* and is connected to it by the box *d*. The lathe face plate *e* carries the lugs *f*, and as the face plate revolves these lugs come against the lugs *g* of the driver, causing rotation. In the figure, *h* is the neck and *i* the body of the roll. The rolls are run in bearings rather than on the centers when turning the body, because the centers do not always wear uniformly during the turning process, and consequently the part

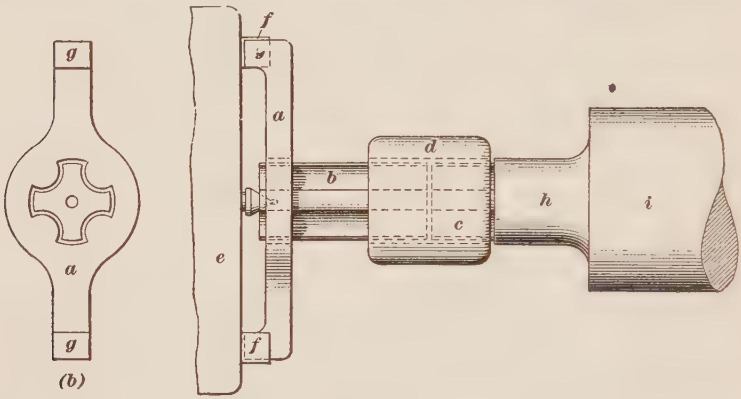


Fig. 15

of the roll turned last would not be concentric with that turned first.

A facing tool, Fig. 5 (*a*), made of high-speed steel is set up against the surface to be turned, the pusher, Fig. 5 (*b*), is placed against the facing tool, and the pusher is held as shown in Fig. 10. By turning the screw *i*, Fig. 10, the tool working against the pusher is forced into the roll and is adjusted until both ends of the portion of the roll turned measure the same. The part of the roll corresponding to the length of the cutting edge of the tool is now turned to the required diameter. All measurements are made with plain calipers.

The tool and pusher are now taken out and reset further along the roll where the tool is forced in as before until this part of the roll is the same diameter as that previously turned. This

process is continued until all parts of the body are turned to the same diameter.

29. The finishing tool, made of high-carbon steel, is next set up in the same manner, and very light cuts are taken until the entire length of the roll body is the same diameter. In case the roll is to be ground and polished, it is not finished quite as carefully in the lathe as would otherwise be done, as it will be trued up accurately on the grinding machine. A little stock, about $\frac{1}{64}$ inch, must be left on rolls to be ground.

30. Testing for Straightness of Surface. The surface of the roll is tested for straightness before removing the roll from the lathe. A straightedge, which has been chalked on its edge with soapstone or hard chalk, is placed lightly on the finished surface and parallel to the axis of the roll. The straightedge is now moved lengthwise about $\frac{1}{16}$ inch, back and forth to produce a rubbing action on the roll. The chalk is thus transferred to the roll at every point of contact. If the roll is finished straight, a line will be transferred on the roll; if the roll is not straight, marks will be found on the high spots only. This test is accurate and reliable, can be easily and quickly made, and is the one commonly used.

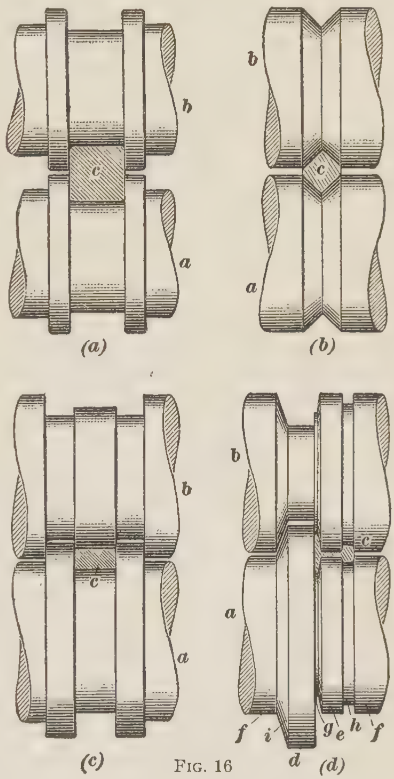


FIG. 16

31. Kinds of Grooved Rolls.—The surfaces of grooved rolls which work together are called **passes.** When the col-

lars, or projecting rings, of one or more grooves fit into corresponding recesses in the other roll, the roll is said to have **closed**

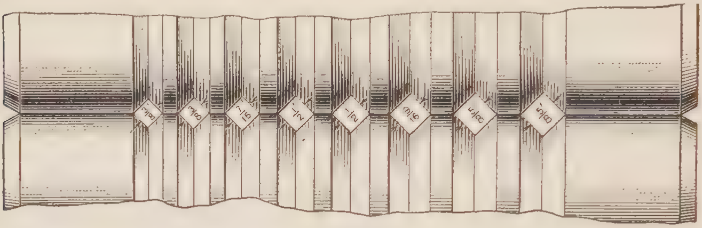


FIG. 17

passes; if the collars do not fit into corresponding recesses, the roll has **open passes.** In Fig. 16 (*a*) and (*b*) are shown examples of grooved rolls with open passes, and in (*c*) and (*d*) grooved rolls with closed passes are illustrated. In the illustrations, *a* and *b* are the rolls and *c* the work being rolled.

32. Templets for Open Passes.—The passes in grooved rolls are turned to fit templets that are generally made of sheet steel or zinc about $\frac{1}{16}$ inch thick. In making templets for open passes either the individual or group method may be followed. Let it be required to make templets for the passes of the rolls shown in Fig. 17. If the individual method is used, a series of templets as shown in Fig. 18 (*a*) are made, and if the group method is followed, the templets are all formed in a single tool as shown in Fig. 18 (*b*). The group method has an advantage in that all the templets for a certain set of grooves are arranged together; but it can only be used for small grooves, for if made for large grooves it would be too clumsy to handle. If no measurement of the templet is over 3 inches, its size is not objectionable. The templets are made so that the wings *a*, Fig. 18 (*a*), on either side of the part *b*

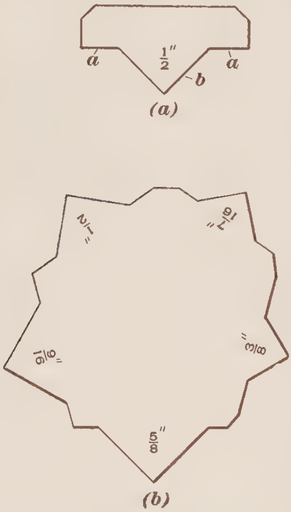


FIG. 18

corresponding to the groove will rest upon the collar of the roll, forming an exact gauge for the depth of the groove.

33. Turning Grooved Rolls With Open Passes.—The shapes of the grooves and their positions in the rolls are determined from the drawing, when turning grooved rolls with open passes. Suppose the drawing, Fig. 17, calls for rolls to roll square bars on the diagonal. As the grooves are, in this case, identical in both rolls, the same tools and templets may be used for both. A roughing tool of high-speed steel and a finishing tool of high-carbon steel of the form shown in Fig. 5 (*d*) are made, the point of the roughing tool being ground off and that of the finishing tool being left sharp. Templets are made to

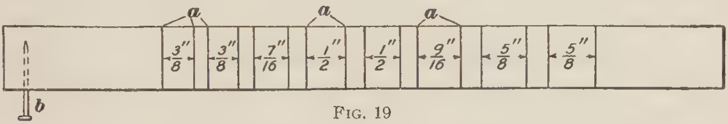


FIG. 19

the dimensions of the drawing, those made of steel being preferable to those made of zinc, as they are less easily distorted or damaged.

34. That the grooves in one roll may coincide and be directly over those in the other roll, a **strip,** Fig. 19, is made. This strip is a piece of wood from 2 to 4 inches wide, $\frac{1}{2}$ to 1 inch thick, and a little longer than the roll body. Lines *a* corresponding to the edges of the grooves are marked on the edge of the strip, and a nail *b* is driven in the end at a distance from the last line marked on the edge equal to the distance shown by the drawing, from the end of the body to the edge of the groove. In use, the strip is held on the body of the roll with the nail against the end of the roll, thus being always held in the same relative position with the roll. By using a strip to locate the positions of the grooves in the rolls, and templets for the size and shape of the grooves, any number of rolls may be turned alike.

To test the fit between the grooves and templets, a piece of white paper is held behind the roll, or rolls, so that a light from some source will shine directly on it. The templet is then held in the pass and if it fits perfectly no light can be seen between

it and the roll. If the groove is not correctly shaped, light will be seen between the templet and the roll.

35. Templets for Closed Passes.—The outline of templets for closed passes is made to correspond to the complete outline of the work to be rolled instead of one-half of this contour, as in the case of templets for open passes. This is necessary as, when fitting the templet to the rolls, they must be together, and consequently a templet of the form described for open passes could not be used. A convenient method of holding closed-pass templets is shown in Fig. 20. The templet *a* is held on the rod *b*, which is about $\frac{1}{8}$ inch in diameter. The end *c* of this rod is threaded to receive a nut *d*, and has a shoulder *e* against which the templet rests. A hole whose diameter is

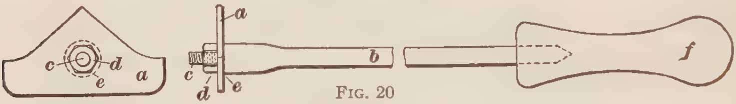


FIG. 20

about $\frac{1}{32}$ inch larger than that of the threaded end is drilled in the templet, and the templet is secured to the rod. In use, the tool is held by the handle *f*.

36. Turning Grooved Rolls With Closed Passes. Grooved rolls with closed passes are sometimes called *collar-and-groove rolls*. They must necessarily be fitted together when turning. This is done by finishing one roll, generally the collar roll, which is the roll carrying the extending part, and then turning its mate, the groove roll, which is the roll recessed to receive the collars, while the finished roll is carried above it on straps shown at *v*, Fig. 4.

37. Suppose the rolls shown in Fig. 16 (*d*) are to be grooved, their bodies having been otherwise turned. As was done when grooving rolls with open passes, a strip, Fig. 19, is made, the division marks being laid off on it in accordance with the drawing. This strip serves as a gauge when spacing the grooves and collars. The collar roll *a*, Fig. 16 (*d*), is finished first. To lay off the grooves, a chalk mark is drawn along the body of the roll parallel with the axis, the strip is placed upon this chalk

mark, a pencil line is drawn the length of the roll, lines are then also drawn on the roll corresponding to the divisions on the strip, and prick punch marks are made at the intersections of these lines.

38. After laying out the location of the grooves and collars, the body of the roll is rough grooved nearly to size. The parts *d*, *e*, and *f*, Fig. 16 (*d*), are now turned to size, and the groove *g* is finished, using a tool of a shape corresponding to that of the groove and the strip and templet as gauges. The tool is fed in until the groove is of the correct shape as shown by the templet. The templet employed in this case is made especially for the groove that forms the flange of the work. The groove *h* is next turned to size, using a tool of the shape of the groove, which is finished to the strip and the complete templet. The part *i* is now turned, using the strip as a gauge, and the

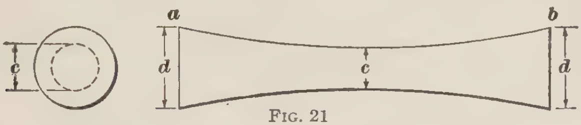


Fig. 21

roll is removed from the lathe and placed on the straps *v*, Fig. 4, after the groove roll *b* has been set in the housings.

The groove roll is now laid off and grooved as was done in the case of the collar roll, except that the straps carrying the collar roll are let down gradually as the groove roll is being finished until the rolls are the same distance apart that they are to be run in the mill. The groove is then finished to fit perfectly the templet, which is held on a rod.

39. Turning Concave Rolls.—Rolls used to roll sheet metals may be of either the hot or cold type and are not grooved. *Hot rolls* are those used to roll hot sheets, and *cold rolls* are employed to roll cold sheets. Owing to the greater expansion in the center part of the rolls when hot, hot rolls are usually made concave, as shown exaggerated in Fig. 21. The shape of the roll is that of a regular curve *a b*. The smallest diameter *c* of the roll is at the center and the largest diameters *d* are at the ends. The rolls are made of such form that

when they are brought together with their axes crossed a certain amount, the contact between the rolls will be a straight line. In operation, the rolls are not crossed. The cross of the rolls is measured by placing a straightedge on the roll at such an angle that no light can be seen between it and the roll, drawing one line along the straightedge, and another line touching the first line at one end of the roll body and parallel to the roll axis, and measuring the distance between these lines at the other end of the roll body. This distance is known as the *cross of the roll.* The cross of the rolls usually varies from 2 to $3\frac{1}{2}$ inches.

Concave rolls are turned so that when a straightedge is placed on them at the proper angle, no light can be seen between it and the rolls. The cutting edge of the tool used for turning the rolls is slightly rounded. Both ends of the rolls are turned to the same diameter, and the center is turned the required amount smaller. Cuts are then taken on the body of the roll until the desired shape and finish are obtained.

40. Size of Rolls for Working Hot Iron.—In turning grooves for rolling-mill work, the grooves must be made somewhat larger than the standard bars they are intended to roll. To meet these requirements, an allowance of $\frac{1}{64}$ inch per inch of diameter is usually considered sufficient. For instance, a tool to cut a groove for rolling a 1-inch round bar would have to be $1\frac{1}{64}$ inches in diameter, and a groove for rolling a $3'' \times \frac{1}{2}''$ flat bar would have to be $3\frac{3}{64}$ inches wide, similar allowances being required for all shapes.

41. Returning Worn Rolls.—Rolls that have been worn from use are usually returned. It will be found that a very hard skin, almost impossible to cut, has been formed on the surface. This skin is very thin and is removed by taking a heavy cut, getting under the skin, before truing up the surface accurately with light finishing cuts. If light cuts are attempted before removing this skin, the tool will be dulled. High-carbon steel is used for both the roughing and finishing tools, as high-speed steel will not retain a good cutting edge.

TURNING HOLLOW ROLLS

42. Lathe for Turning.—Rolls for flouring mills, calendering rolls for paper mills, and rolls for other similar purposes are generally cast hollow and chilled on the outside. These rolls are usually turned on a special type of lathe, Fig. 22, and, in the case of flouring-mill and calender rolls, are ground to a perfect finish while running on their own bearings.

Both spindles of the lathe are made hollow and the roll is introduced through them and the collars *a*, Fig. 22, and is held in position by the setscrews *b*. In the lathe shown, both spindles are fitted with gears, the roll being driven from both ends, thus increasing the rigidity of the lathe. The shaft *j* is driven by any convenient means. The pinion is keyed to this shaft and drives the gear which is keyed, together with the pinions which drive the spindle gears, to its shaft. This style of lathe is not provided with a carriage having a feed parallel to the length of the lathe, but simply with a broad tool post *d* fitted upon a cross-slide *c* that can be fed along the ways *e* by means of the feed-screw *f*.

Lathes driven from one end only are also used for turning hollow rolls. In this case, the tailstock end of the lathe is made with a hollow spindle through which the roll can be introduced.

43. Holding and Driving Work.—Hollow rolls are first set up in the lathe; the chilled surface is then turned, and the ends are cut off, after which the rolls are bored and fitted to a center piece which forms the shaft and journals. Ordinarily, in turning 10- or 12-inch rolls that are to be bored and mounted subsequently, the roll is held by means of eight setscrews at each end, these setscrews also acting as drivers. Fig. 23 illustrates the general method of driving. In Fig. 22 can be seen the collar *a* through which the setscrews *b* are passed to hold the work. The same letters have been used for referring to these parts in Fig. 23. The roll *r* is centered and held by means of the setscrews *b*. This method of adjusting and driving the roll enables the workman to center the chilled part very carefully, so that

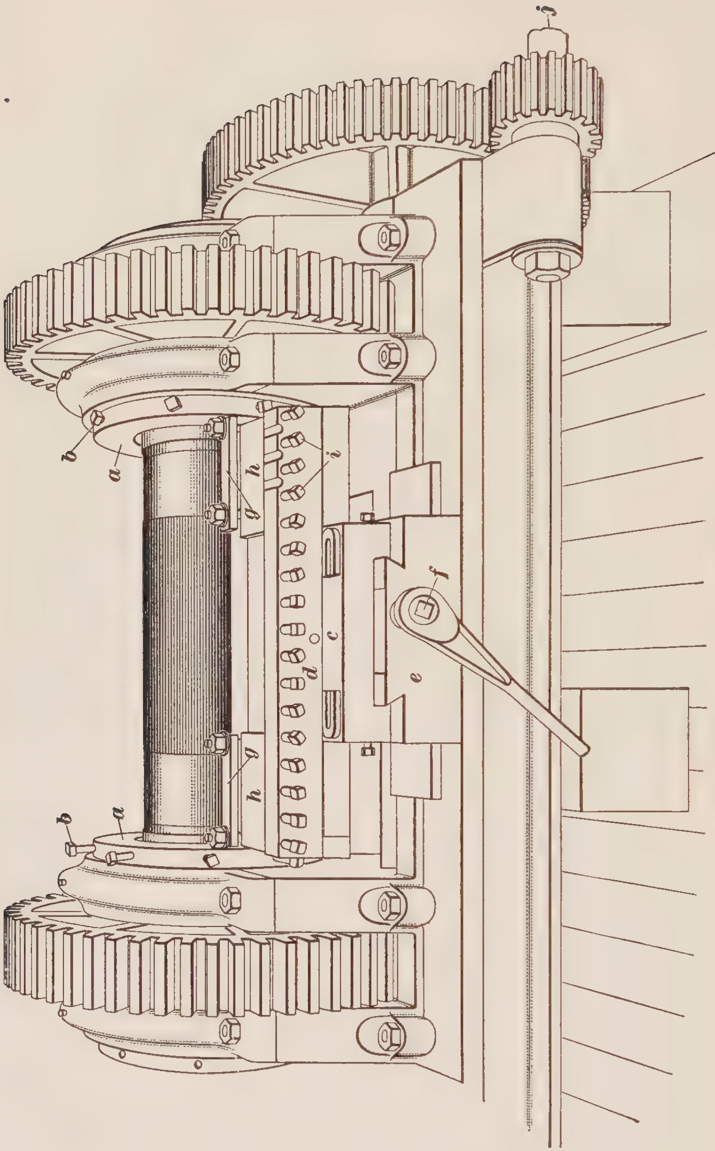


FIG. 22

the amount of turning required will be as small as possible. There is generally about $\frac{1}{8}$ to $\frac{3}{16}$ inch of stock to be turned from chilled rolls, and as the turning process is very slow it is important that the centering be done accurately and carefully.

44. Holding Lathe Tools.—Tools for turning hollow chilled rolls must be clamped to the lathe tool rest very rigidly. The method of holding the tools is illustrated in Figs. 22 and 23. In Fig. 23 the tool *c* is set on the carriage *h* and clamped down

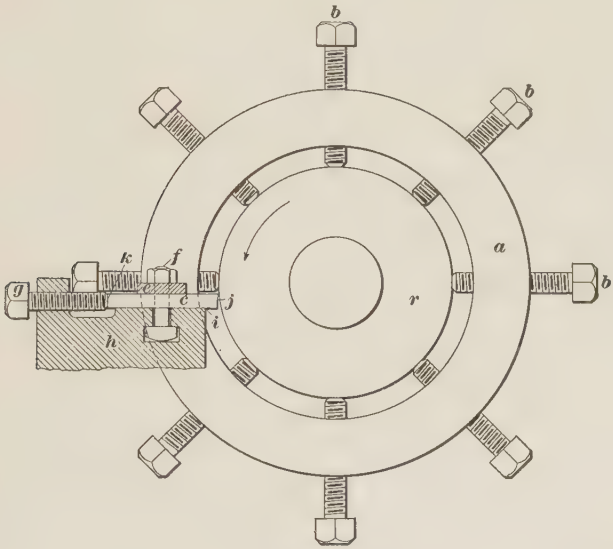


FIG. 23

by means of the strap *e*, which is held in position by two bolts *f*. The tool is forced against the rolls by means of a series of set-screws *g*. Care must be taken that the front face of the rest is close to the roll, as shown at *i*. The closer this rest is to the roll, the less danger there will be of breaking the front face of the tool. The flat tools employed for this work may be originally $\frac{1}{2}$ in. × 5 in. × 5 in. If the tool is ground on one face only, but two cutting edges can be obtained from one grinding. If the tool is ground on both faces, as *j* and *k*, four cutting edges will be obtained. When these have been dulled,

the tool is ground again, and each succeeding grinding makes it narrower. Tools can be used until they become so narrow that they can no longer be held by the clamps *e*. In Fig. 22, the clamps can be seen at *g*; in this case very narrow tools are being employed and packing pieces *h* are placed behind them for the setscrews *i* to bear against.

45. The upper edge of the tool *c*, Fig. 23, is set $\frac{1}{2}$ inch below the center of the 10-inch roll. This, together with the concave form of the face, will give the proper amount of clearance. In setting cutting-off tools, they are clamped by means of one or more clamps similar to *e*, Fig. 23, and the back end of the tool is set against a setscrew or a packing piece held by two or more setscrews. Cutting-off tools must overhang the front edge of the rest *i*, Fig. 23, to a greater extent than turning tools, and consequently it is necessary to have the tool deeper from the top to the bottom, so that it may be stronger.

After the tools have been clamped in place they are fed to the work by means of the feed-screw *f*, Fig. 22, and are kept parallel with the face of the work by adjusting the setscrews *i*. The shavings cut from the roll resemble very fine needles or gray hair.

46. Turning Hollow Rolls.—The tools commonly employed for turning hollow rolls are flat broad-nosed or wide-faced tools. It is probable that $\frac{1}{2}$ in. $\times$ 5 in. $\times$ 5 in. is about an average size for straight work. In turning cylindrical rolls two tools are commonly operated at a time, thus turning 10 inches of the face of the roll. At first thought it might seem best to use one tool 10 inches wide; but it is difficult to harden so wide a tool without cracking it; narrow tools are far less likely to break, and on the whole there is greater economy of steel and less difficulty experienced in adjusting tools when the two 5-inch tools are employed in place of one 10 inch. All tools for turning chilled iron differ radically from those employed on softer metals, and all the turning is of the nature of scraping, the tools being given but little, if any, clearance.

47. When cutting off the ends, the roll is never entirely cut off on the lathe but is cut down until it has a shell about

$\frac{1}{4}$ inch thick about the core. It is then removed from the lathe and iron wedges are driven into the cut made by the cutting-off tool to force the end off. The roll is bored with ordinary tools in another machine, the central portion of the roll being soft.

GRINDING CHILLED ROLLS

48. Roll-Grinding Practice.—Chilled rolls intended for use in flouring mills, calender rolls for paper-making machinery, and others requiring a smooth, cylindrical surface are finished by grinding. The necks as well as the bodies of the rolls may be ground. In some cases the necks are left as they come from the lathe and in others they are ground previously to grinding the bodies. If the necks are not cylindrical and the rolls are ground while they are running in bearings, the body of the roll will not be ground cylindrically. For this reason, where accuracy is required, the necks are generally ground.

49. Poole Grinding Machine.—The J. Morton Poole grinding machine is much used to grind large rolls. It is arranged with the grinding wheels in swinging frames to grind the roll cylindrically, regardless of slight inaccuracies of the ways. To secure the best results in grinding a roll on this machine, the necks must have been previously ground true, by grinding on dead centers in the usual way on a cylindrical grinding machine of the ordinary type.

50. Cylindrical Grinding Machine.—A cylindrical grinding machine adapted to roll grinding is shown in Fig. 24. It can be used to grind both the necks and bodies of the rolls, the necks being ground on dead centers, and the bodies while the necks are running in bearings. This machine is similar to the cylindrical grinding machines in ordinary use, being of the type in which the table *a* is stationary while the grinding wheel *b* and the carriage *c* which contains it, traverse past the work *d*. This type of machine is especially adapted to the grinding of long heavy rolls, as the roll does not traverse back and forth when grinding. The table of such a machine is more rigid and less floor space is needed.

51. The grinding wheel is driven by a belt *e*, Fig. 24, operating from the main drive shaft *f*. This shaft extends the entire length of the machine, and from it the different mechanisms are driven independently through belts. It is protected by a sheet-metal guard *g*. The grinding-wheel belt *e* passes over idlers *h* that are arranged so that the belt is maintained taut on the pulleys as the wheel head is moved on the cross-slide. The carriage *c* travels lengthwise on the **V** *i* and the flat *j*. These ways are protected from grinding dust and dirt by the guards *k*. When grinding the necks of the roll, the roll

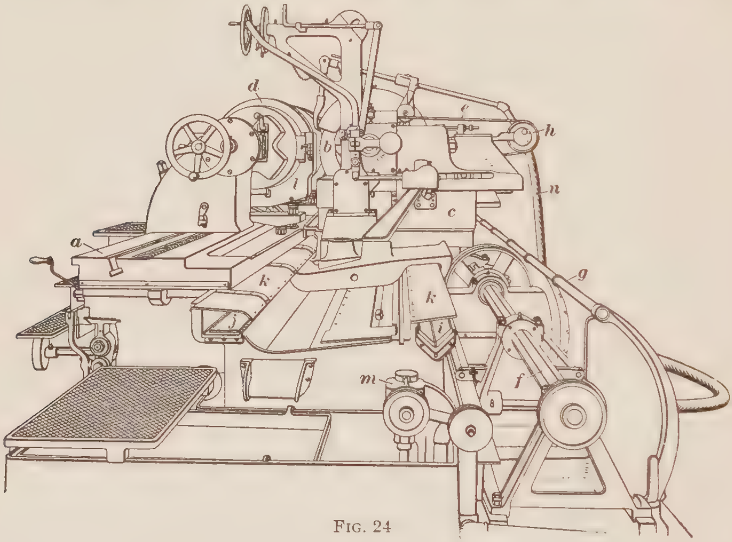


FIG. 24

is supported on dead centers in the usual way. When grinding the body of the roll, the necks rest in the bearings *l*, the roll being connected to the headstock, not shown, in any convenient way to cause rotation. The headstock spindle and the main shaft *f* are driven by a motor located at the end of the machine, not shown. They may be driven, if desired, by belting connected to an overhead countershaft. A liberal supply of soda water is furnished to the wheel when grinding by the pump *m* through the hose *n*. The speeds and feeds of the machine are controlled by hand wheels and levers.

52. **Selection of Grinding Wheel.**—In grinding chilled-iron rolls, as in turning them, the degree of hardness of the metal will, to a great extent, govern the working of it, the softer roll being ground much more rapidly than the harder. The selection of the grinding wheel must be made with the aim in view of producing a highly polished surface and a rapid removal of stock. The harder the iron, the softer in grade should be the wheel for best results, and the finer the grain of the wheel, the more highly polished will be the surface produced. In general, for grinding chilled iron a soft or medium soft grade of wheel and a grain of from 60 to 80 will be found satisfactory. For grinding the necks of the rolls, which are not chilled, a wheel of harder grade might be used. The same result may, however, be obtained by speeding up the grinding wheel.

53. **Grinding Speeds and Feeds.**—The surface speed of the rolls, when grinding, varies from 20 to 60 feet per minute, and the depth of cut varies from .00025 to .004 inch. When grinding hard chilled iron with a depth of cut of .004 inch, the roll is run slowly, at a surface speed of about 20 feet per minute. A traverse speed of the wheel of about $2\frac{1}{4}$ inches per revolution of the work would be good practice for this case. It is best to use this traverse speed, because by so doing the grinding wheel cuts and consequently wears evenly over almost its entire face. If a lower traverse speed were used, one corner of the wheel would do all the heavy work and the face would be worn out of shape very quickly.

After the roll has been roughed down nearly to size, a cut of .0015 to .002 inch in depth with a traverse speed of about 1 inch per revolution of roll and a surface speed of about 45 feet per minute is taken. When finishing the roll, the surface is run at about 60 feet per minute, the traverse speed is lowered to about $\frac{1}{8}$ inch per revolution of work, and cuts of from .00025 to .0005 inch are taken. With a light cut, a high surface speed, and a slow traverse speed, a surface, mirrorlike in appearance, can be ground. A grinding wheel made of alundum, aloxite or adamite, and operating at a surface speed of from 5,500 to 6,500 feet per minute, will give good results.

54. Grinding of Rolls.—When grinding rolls, the necks are ground on the dead centers in the usual manner. The bearings for carrying the rolls are now put on the table of the machine and adjusted to the necks of the rolls, and the tail-stock center is adjusted to the work to prevent an endwise movement. A cut is then taken over the roll and the work is calipered on both ends to determine whether the roll is being ground cylindrically. If the roll is found to be smaller at one end than the other, proper adjustment is made and another cut is taken. When grinding, plenty of soda water must be kept running on the part being ground, to avoid burning the surface of the roll.

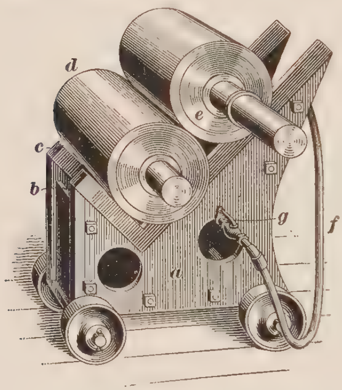


Fig. 25

55. Testing Rolls.—If the rolls are properly ground they should fit perfectly, and in order to test them a chalked straightedge, such as was used to test the straightness of the rolls when turning, may be employed. The arrangement shown in Fig. 25 is sometimes used to test the straightness of the rolls. A small carriage *a* is provided with carefully planed parallels *b* and *c* which are inclined so that the rolls will lie in contact. Two rolls are laid on these parallels, as shown at *d* and *e*. The hose *f* is connected to a gas fixture and a series of gas burners are arranged on the pipe *g* so that they furnish a bright light back of the joint between the rolls. Electric light may be used in place of gas light. If the work has been properly done, no light whatever can be seen between the rolls, as they rest on each other and on the parallels. An extremely delicate test of the accuracy of the workmanship on the rolls is thus given. The straightedge test will usually be found more satisfactory when testing large rolls and the testing device when testing small rolls.

PLANING AND DRILLING CHILLED IRON

56. Tools for Planing Chilled Iron.—It is frequently necessary to plane chilled-iron dies for pressed-brick machines, swage or anvil blocks, drop-hammer dies, guides for rolling mills, and similar purposes. This work may be accomplished by making the speed of the ordinary planer sufficiently slow and the tools sufficiently rigid. Best results are obtained by the use of very rigid machines. In some cases, the planing is done by feeding a broad, square-nosed planing tool directly down on the face of the work, a slight amount of feed being given after each cut. When the width of the tool has been finished, it is moved along and a corresponding cut taken down to the proper depth. This method of procedure is exactly like that employed in turning chilled rolls.

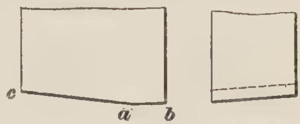


FIG. 26

57. In other cases a fairly broad-nosed planing tool is adjusted so that it will act both as a roughing and a finishing tool and is given a slight feed across the planer after each cut, the cutting edge of the tool being of the general form shown somewhat exaggerated in Fig. 26; the portion *a b* is parallel to the surface of the work to be planed, and the portion *a c* is inclined so that it will act as a roughing tool to prepare the surface for the finishing cut. Such a tool is given a very slight clearance. This practice of feeding sidewise in planing may be followed where it would not be possible to do so in lathe work, because all the feed occurs at the end of the stroke before the tool begins to cut, while in lathe work the tool must be fed sidewise during the cut.

FIG. 27

58. A form of planing tool used only for roughing is shown in Fig. 27. This tool takes two cuts, the parts *a* and *b* doing the

cutting. Chilled iron which has been rough-planed with a tool of this form is finished with a broad-nosed tool.

59. Special Forms of Planing Tools.—Chilled rolls are sometimes grooved lengthwise. A tool and holder used to plane grooves of this form is shown in Fig. 28. The tool *a* contains a projection *b* which slides in the slot *c* of the holder *d*. The tool is clamped in any position by means of the yoke *e* and the screw *f*. The sides *g* of the tool are machined to such a shape that the tool, when its face *h* is ground square with the work, will cut a groove of the shape desired. The tool is sharpened by grinding on the face *h* only. The tool holder, yoke, and screw are made of machinery steel, the roughing tool of high-speed steel, and the finishing tool of high-carbon steel.

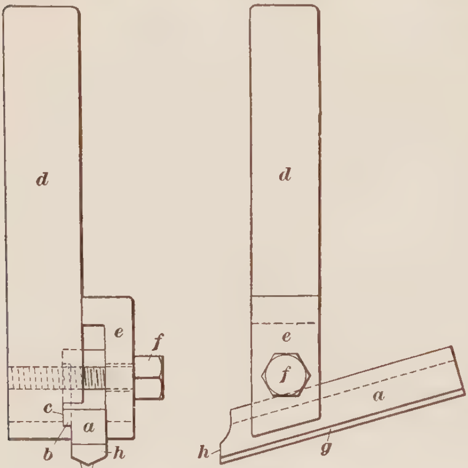


Fig. 28

60. Corrugated Rolls.—Some of the rolls employed in flouring mills must be corrugated after they are turned and ground. The corrugations are shallow grooves planed in the face of the rolls; they are not parallel to the length of the roll, but have a slight spiral. These grooves are found necessary in certain classes of grinding rolls, not only to cause material to feed properly, but to produce the desired result upon the material being ground.

61. Corrugating Machine.—The machine employed for corrugating rolls is similar to a planing machine. One type of this class of machine is illustrated in Fig. 29, in which *a* is the roll being grooved. The weight of the roll is being carried on

bearings *b*. The tailstock *c* is provided with a center that prevents any lengthwise movement of the roll, and the headstock *d* is furnished with the necessary mechanism for rotating the roll through the proper angle to give the desired spiral. In the type of machine shown this is accomplished by means of a worm-wheel *e* and a worm *f*. The worm is made long and serves as a rack. It is moved crosswise by the slide *g* traveling in the slot *h*, which may be set at any desired angle with the ways of the machine. The slide carries the worm across the grooving

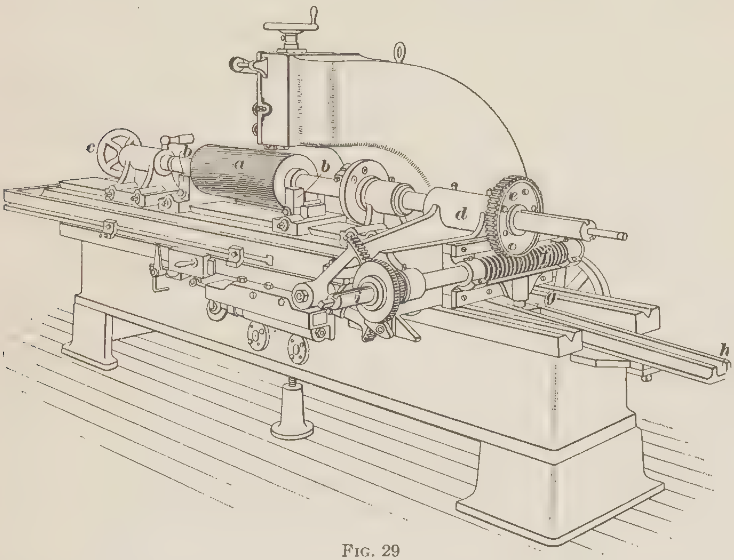


FIG. 29

machine as the roll advances, and so rotates the worm-wheel *e* through a portion of a revolution during each stroke of the machine, thus producing a spiral groove. The proper number of divisions or teeth are obtained by means of an automatic spacing device shown on the worm-shaft *i*. This spacing device gives the shaft *i* a portion of a revolution after each stroke of the machine, thus advancing the roll to the next space.

62. Corrugating the Rolls.—In corrugating rolls, a wide tool similar to that shown in Fig. 30 is employed. This tool is made of $\frac{3}{4}'' \times 1\frac{1}{2}''$ steel. The tool is milled on the end

with the kind of corrugation wanted, after which it is hardened. The tool is so set in the machine that it starts to cut on one side and each succeeding tooth takes a deeper cut, until the last one finishes the cut to the required depth. This method may be used if the corrugations are not so large that considerable metal must be removed, when it may be necessary to go around the roll twice to finish the grooves.

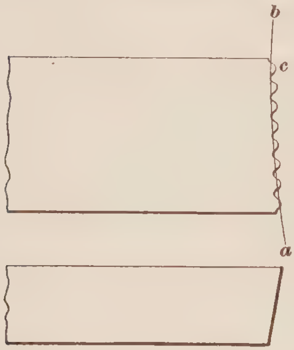


FIG. 30

63. In ordinary practice it is impossible to take a cut of over .015 inch in planing chilled iron, and, unless wide tools with a number of teeth are employed, it will take a very long time to do the corrugating. In Fig. 30 the curved line *a b* represents the circumference of the roll, and each succeeding tooth takes a slightly deeper cut than the preceding, the tooth *c* finishing the groove.

64. Drilling Chilled Iron.—Drills for drilling chilled iron are made of high-carbon steel and of the form shown in Fig. 31. A twist drill would not be strong enough to withstand the hard service. The point of the drill, instead of being ground to the regular angle of drills, is ground very flat, the angle *a* being from 165° to 170°. The tool is carefully hardened and a little clearance is ground on the cutting faces. When drilling, considerable pressure must be applied to the tool, and it must be turned quite slowly. Turpentine is used as a lubricant.

FIG. 31

BENCH, VISE, AND FLOOR WORK
(PART 1)

BENCH AND VISE WORK

1. Explanation of Terms.—The machine-shop operations previously considered have been almost entirely associated with machine tools. Aside from these, a large amount of work is done by hand, such as laying out, chipping, filing, scraping, fitting, etc. These operations are usually performed either on a bench, in a vise, or on the floor, depending on the nature and size or weight of the work; hence, the name *bench, vise, and floor work*.

Bench and vise work is of a lighter nature than floor work, though it may, and often does, include the entire finishing and erecting process where the machine is small, and in the case of large work many of the small parts are assembled at the bench and are then taken to the floor and adjusted to the other parts.

Floor work includes the erecting and assembling of heavy machines and the machining of parts too heavy or too large to be operated on in the stationary machine tools. In the latter case, the heavy parts are set up at a convenient place on the floor and the machining done by means of portable tools set up at a suitable location for each operation.

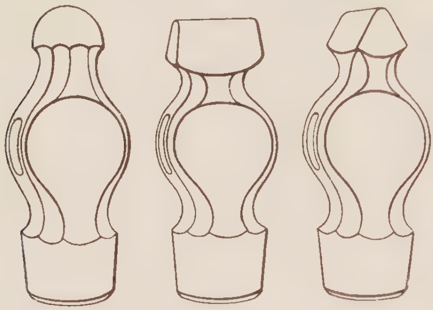
TOOLS AND FIXTURES EMPLOYED

TOOLS

2. Hammers.—The hammers used by machinists weigh from $\frac{1}{4}$ to 2 pounds, and are designated as *ball-peen*, *straight-peen*, and *cross-peen*. The ball-peen hammer, weighing from 1

to $1\frac{3}{4}$ pounds, and shown in Fig. 1 (*a*), is most commonly used by machinists for all ordinary work, including riveting, and the effect of the blow struck by the ball is equal in all directions. The straight-peen (*b*), and cross-peen (*c*), are employed when the effect of the blow must be greater one way than the other. The smaller sizes of hammers are used on light work.

3. Hammer Handles.—In Fig. 2 (*a*) is shown the form of hammer handle used. The handles vary in length from 10 to 21 inches, depending on the size of the hammer, and are made of the best quality of white, straight-grained, second-growth, well-seasoned hickory. The handle is fitted to the eye in the hammer head so that it fills the eye as nearly as possible. The handle is set at right angles to the head of the hammer, so that when a blow is struck the head will fall squarely.



(*a*) (*b*) (*c*)

Fig. 1

The eye in the hammer head is made larger at its ends than at the middle, and the handle is wedged in the eye so that it will be held securely in the head. The eye is widened sidewise, or lengthwise, or both sidewise and lengthwise, from the middle of the head toward the outside.

If the widening is sidewise only, one wedge is used as shown at *a*, Fig. 2 (*b*). If the eye is widened at the top and bottom, and not at the sides, two wedges are driven crosswise as shown at *a* in (*c*). If the widening is in both directions, three wedges are used as shown in (*d*). The wedges are made of wrought iron or soft steel.

4. Center and Prick Punches.—Center punches, illustrated in Fig. 3 (*a*), are used to punch the centers of holes to be drilled. The prick punch shown in (*b*) is similar to the center punch, but is smaller. The prick punch is only employed

to make the light marks in laying out work, while the center punch is used to make a larger hole and often to move a center hole one way or another. Center and prick punches must have sharp, well-ground points, the angle of the point being about 60°.

5. **Special Forms of Center Punches.**—Work must sometimes be laid out similar to a model or templet. When

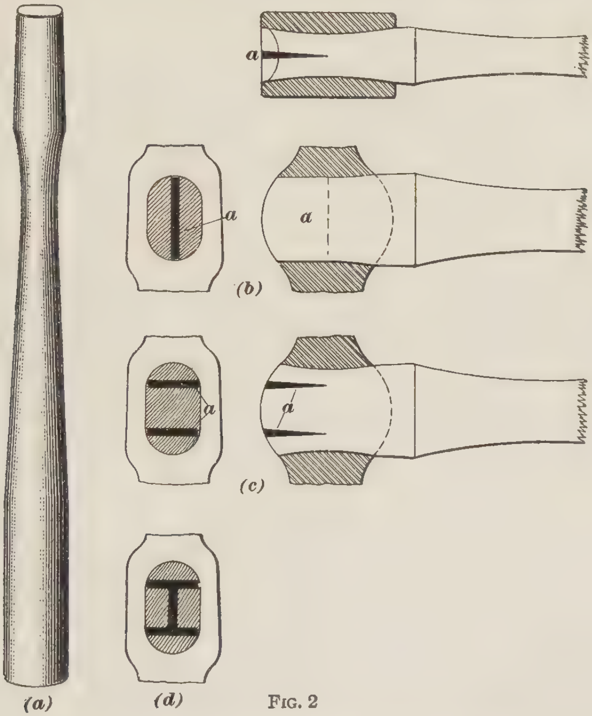


FIG. 2

this model or templet contains holes that must be similarly located in the work, a center punch as shown in Fig. 3 (*c*) may be used. By putting the cylindrical part *a* of the punch through the holes in the model or templet and striking a blow on the head of the punch, the point *b* is driven into the work. The diameter *c* of the punch must be the same as the diameter of the guide hole in the model or templet.

Holes that are laid out for drilling have a circle drawn to their diameter with a pair of dividers. Where large numbers of these are to be drawn, a tool like that shown in Fig. 3 (*d*) is useful. This may be made from a piece of round steel turned as shown at *a*, making a center punch surrounded by a sharp ring *b*. The point of this tool is placed in the prick-punch mark that shows the center of the hole, and a blow on the head of the tool locates the circle. In some cases, the diameter *b* of the tool is made the same as the diameter of the hole to be

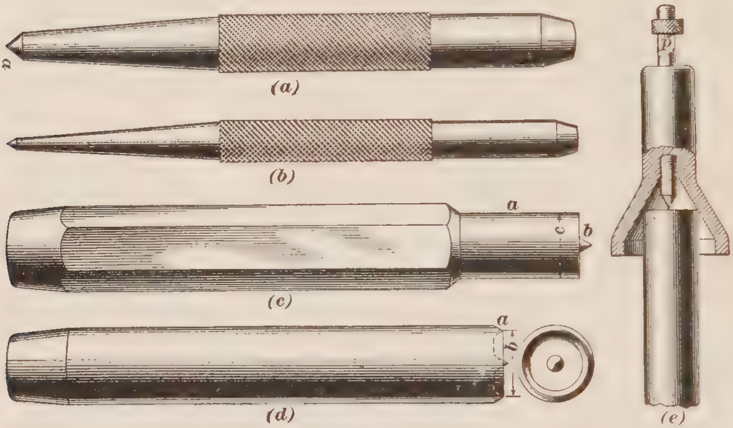


FIG. 3

drilled, though for some work it is made larger than the hole and shows whether the work has been properly drilled.

A form of centering tool, known as a cup center and shown in Fig. 3 (*e*), is sometimes used for centering round work. When the tool is placed on the work as shown and a blow is struck on the pin *p*, the point is driven into the center of the work.

6. Scribers.—One form of scriber in common use, shown in Fig. 4 (*a*), may be made of a piece of $\frac{3}{16}$-inch steel wire, from 6 to 10 inches long. It is twisted in the middle so as to be easily held in the hand, and one end is bent at right angles to the main part. The points are ground sharp and the scriber is hardened and tempered. It is used for drawing lines in laying

out work. One form of improved scriber with nurled handles and inserted scribing points is shown in Fig. 4 (*b*).

7. Bench Centers and Straightening Press.—The bench centers illustrated in Fig. 5 are for the convenience of the viseman in centering work for the lathe. The centers *a* and *b*

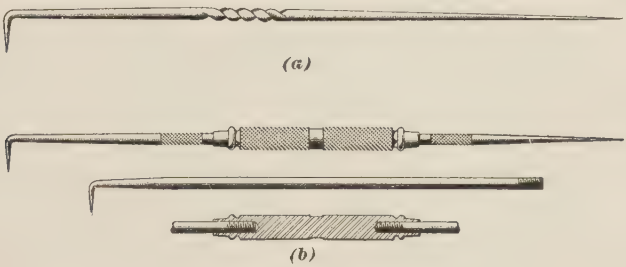


FIG. 4

may be set at any location along the rod *c*. The head *d* is provided with either a spring or a screw center, so that the piece can easily be put in place or removed.

The piece to be centered is put in the vise, center-punched, put in the bench center, and rotated to show whether it runs out, and how much. The side out of center is marked with chalk, and the center hole drawn toward that side with the center punch. This operation must be repeated until the piece runs true enough to finish. If the middle of the piece is out of true or is crooked, it should be straightened by hammering or by bending in the screw-straightening press *e*, back of the centers. The straightening press consists of two movable **V** blocks *f* resting on a base *g*, and a screw *h* with a **V** point on the lower end, the screw being supported in a frame, as shown. To straighten a piece, it is laid upon the blocks *f*, with the bend up, and the screw lowered until the bend is removed.

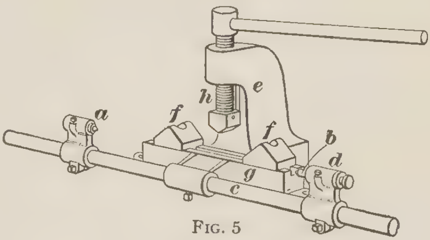
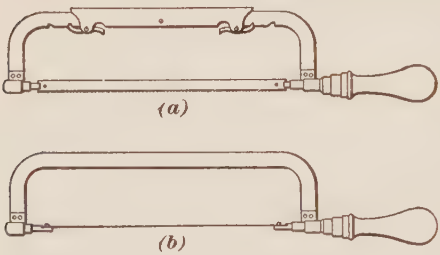


FIG. 5

8. Hand Hack Saws.—The hack saw consists of a frame and blade. Some of the frames are made to employ one size of blade only, while others are made to use blades of two or three different lengths. The hack-saw blades are made in lengths of from 6 to 36 inches, and may be used either in hand frames or in specially designed power machines.

The hand frame illustrated in Fig. 6 (*a*) is an adjustable frame in which blades from 8 to 12 inches long can be used. The clamps holding the ends of the blade may be set in four positions, which allow the saw to be operated in any desired direction. Fig. 6 (*b*) shows the blade set at right angles to the plane of the frame to cut lengthwise of the piece. In hand work, the operator should raise the frame slightly when drawing the saw back; otherwise, the back stroke is destructive to the teeth.


(*a*)
(*b*)
Fig. 6

9. Power Hack Saw.—A power hack saw is illustrated in Fig. 7. It is provided with a vise for holding the stock to be cut off, and is made to stop automatically when the piece is cut through. The blades used in the machine are generally 12 or more inches long; they will cut stock as large as 4 inches in diameter. The power saw has a great advantage over the cutting-off machine, in that it will cut stock of any irregular section. It is especially adapted to cutting off tool steel, which it does quickly, with very slight waste. The saw frame of this machine has an upward motion during the back stroke that lifts the teeth off the piece being sawed, thus saving the points of the teeth.

10. Hack-saw blades are so hard that they cannot be filed, and are thrown away when dull. They are made with about 25 teeth per inch for sawing thin metal, brass tubing, and pipe, and with about 14 teeth per inch for other work. The 8-, 10-, and 12-inch blades used in hand frames are about $\frac{25}{1000}$ inch

thick and $\frac{1}{2}$ inch wide. Longer blades are generally used in the power-driven hack saw than in the hand hack saw, as in the power machine the blade is guided uniformly in a straight line, whereas in the hand hack saw the blade is likely to run unevenly, and so be cramped and broken. The blade commonly

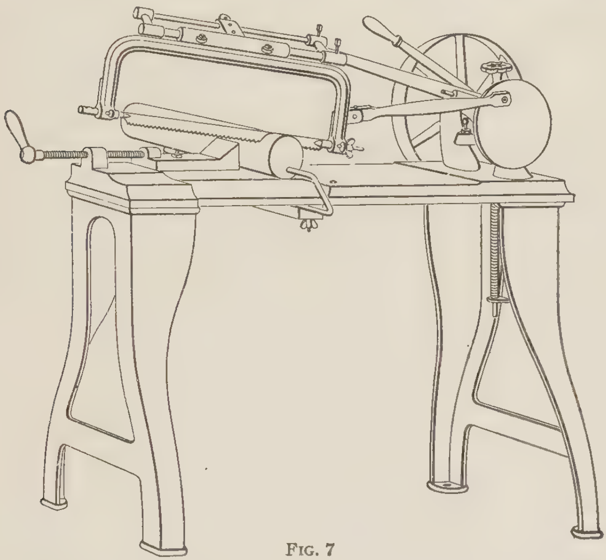


FIG. 7

employed in the machine has about 12 teeth to the inch, is about $\frac{3}{100}$ inch thick, and $\frac{5}{8}$ inch wide.

Hack-saw blades, while very hard, have a fair amount of elasticity; 10-inch blades of the best makes may be bent to a half circle without breaking.

WRENCHES

11. Single-End Wrenches.—Two classes of single-end wrenches are manufactured. An *open-end wrench* is one that encloses three sides of a square, or four sides of a hexagonal nut or head; a *closed-end wrench* is one that entirely surrounds the nut or head. Open-end wrenches have certain advantages, in that they need not be slipped over the end of the bolt or nut;

they are made both with the sides of the jaws parallel to the line of the handle and with the sides of the jaws set at an angle to the center line of the handle.

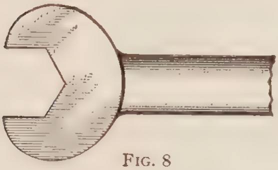


FIG. 8

12. For some purposes the **straight single-end wrench** with the sides of the jaws parallel to the handle, as illustrated in Fig. 8, is suitable; but for work in contracted spaces an **offset wrench** is more convenient. The offset should be 15°. The manner of using the wrench is illustrated in the four views in Fig. 9. The wrench handle *b* operates between the obstructions *c* and *d*. The wrench is first placed on the nut *f* as shown in (*a*), and the handle moved to the left into the position shown in (*b*). The wrench is then turned

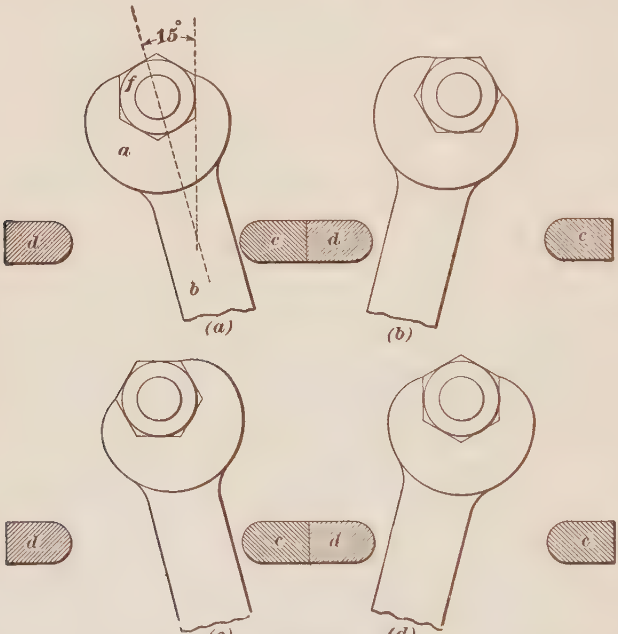


FIG. 9

over and placed on the nut, as illustrated in (*c*), when it may be given another movement, bringing it into the position shown

in (*d*). The nut will have been advanced $\frac{1}{6}$ of a turn in 2 moves; therefore, 12 movements are necessary to make a complete turn. If the wrench were made straight, as shown in Fig. 8, it could not be operated in the manner illustrated in Fig. 9, and the nut would have to be so located as to allow a clear space in which the wrench could make $\frac{1}{6}$ of a turn.

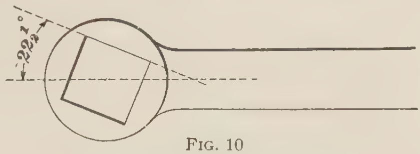


FIG. 10

13. The open-end wrench is especially adapted for screwing on nuts, screwing in cap bolts, etc.; but for operating taps and other work, a **closed-end wrench** similar to that shown in Fig. 10 is often used. The sides of the jaws may be made parallel to the handle, as shown in Fig. 8, or offset, as shown in Fig. 9. If the wrench is intended for a square-end tap, the offset should be one-half of 45°, or $22\frac{1}{2}°$, as shown in Fig. 10. This will enable the operator to advance the tap $\frac{1}{8}$ of a turn in case there are obstructions so placed that it is impossible to make a greater fraction of a turn.

14. Double-End Wrench.—The wrenches used for turning taps and hand reamers are made in several forms. Some are made solid, with one or more holes for different-sized shanks; but the wrenches most commonly used are made of the form shown in Fig. 11. This wrench is adjustable to several different sizes of tap squares. The length of the handles of different wrenches of this type are proportionate to the diameters of the taps on which they are to be used. Holes must frequently be tapped in spaces where wrenches of this type cannot be turned, and the single-end wrench must be substituted; but,

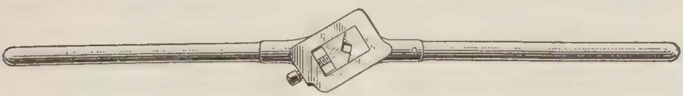
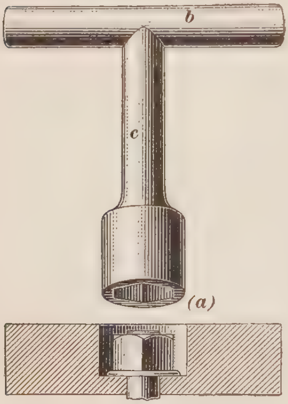


FIG. 11

where practicable, an extension should be placed on the tap and a double-end wrench employed, as by this means holes

can be tapped more nearly true and the danger of breaking the tap is less.

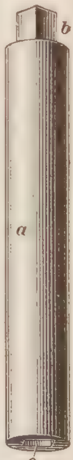
15. Socket Wrenches.—The most common form of socket wrench is illustrated in Fig. 12 (*a*). It is used to turn nuts and bolt heads set in recesses below the surface of the work, as shown in (*b*). These wrenches are made with either square or hexagonal sockets, as the work may require. The sockets are made by laying out the desired form on the end, drilling one or more holes to remove the majority of the stock—in the case of a large wrench, chipping out some of the remainder of the stock, and then broaching the hole to the desired form.



(*b*)

FIG. 12

16. When it becomes necessary to tap holes or to screw in studs or bolts in contracted spaces, the work may sometimes be reached by means of a **socket extension** similar to that shown in Fig. 13. This consists simply of a long stem *a* having at one end a socket *c*, of the form required to fit the work, and a square *b* on the other end intended to fit a single- or double-end wrench. Usually, these socket extensions are used only with double-end wrenches.



c

FIG. 13

17. Ratchet Wrenches.—With practically all single-end wrenches, the wrench must be removed and replaced on the nut after a portion of a turn has been made. As there are a great many places where only a single-end wrench can be used, much time is lost in changing the wrench. To prevent this, ratchet wrenches are employed. In one form of adjustable ratchet wrench, illustrated in Fig. 14, the jaws *a* can be so adjusted by means of the screws *b* that they will accommodate a number

of sizes. A handle *c* can be moved forwards through whatever portion of a stroke the location will permit, and then return for another stroke. Even as little as one tooth *d* of the ratchet

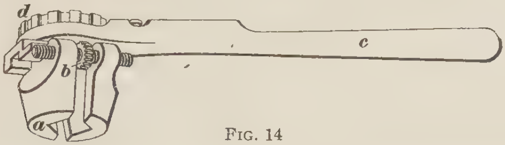


FIG. 14

may be moved. This style of ratchet wrench has but a single pawl engaging the ratchet, and hence there will be some lost motion before the pawl engages a tooth on the forward stroke.

18. The teeth of the ratchet should be as coarse as possible, to give them the requisite strength. Then, in order to get the least amount of lost motion, the multiple-pawl ratchet is used. This form is illustrated in Fig. 15, in which the ratchet *a* has 12 teeth; 5 pawls *b* are so placed that only one of them will

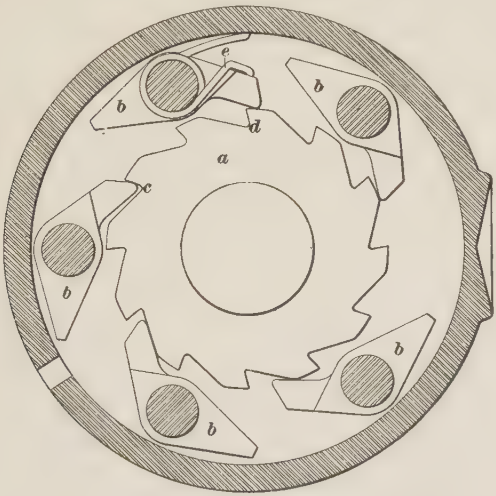


FIG. 15

engage a tooth at a time, as shown at *c*. By moving the pawls back $\frac{1}{5}$ of a space between the teeth, the next pawl will come in contact as at *d*, and hence the lost motion cannot be greater

than $\frac{1}{5}$ of, $\frac{1}{12}$ or $\frac{1}{60}$, of a turn. The pawls are kept in contact with the ratchet by springs, as shown at *e*.

19. Studbolt Wrench.—For driving studs by means of a ratchet, a special stud holder, shown in Fig. 16, is provided. The stud *a* is screwed into the socket *b*, and then the point of the setscrew *c* is run down against the end of the stud so as to

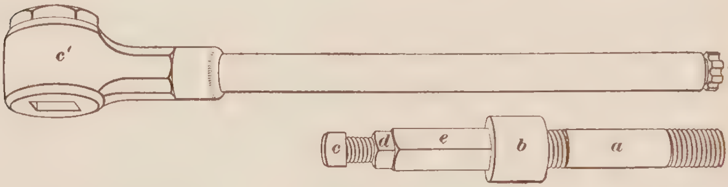


FIG. 16

lock it in the socket. The setscrew *c* is held in place by means of a locknut *d* and the stud driver is operated by means of a ratchet *c'* on the square *e*.

Ratchets may be applied also to socket extension wrenches where these are in locations in which a complete turn cannot be made.

20. Pipe Tongs.—Iron pipe is screwed together with wrenches of various forms, some of which are shown in the following illustrations: Fig. 17 shows the most common form, commonly called *pipe tongs*, one size being provided for each

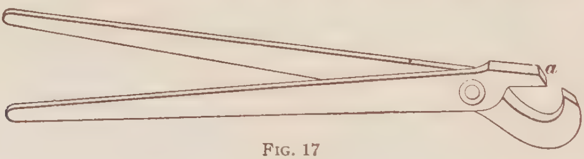


FIG. 17

separate size of pipe. This general style is also made with the jaw *a* adjustable and controlled by a screw, so as to adapt one pair of tongs to several sizes of pipe.

The *chain tongs* shown in Fig. 18 is especially adapted to work on large pipe. The handle *e* has two steel jaws *a* cut on both sides. A chain *b* made fast to the bolt *c* permits both sides of the jaws to be used. The tongs are rotated in the direction

of the arrow. Tongs of this type are made of various sizes for use on all sizes of pipe. Chain tongs are the most rapid tools of their kind for medium and large work.

21. Pipe Wrenches.—The *Stillson pipe wrench*, illustrated in Fig. 19, is an adjustable wrench. It has a movable

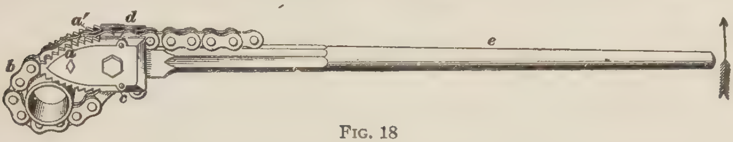


FIG. 18

jaw *a* moved by the milled nut *b*, and may be used on several sizes. Although made particularly for pipework, it finds many other useful applications. When in use, the wrench is turned in the direction of the arrow. *Alligator wrenches* have a **V**-shaped opening in one end, and in the smaller sizes in both ends. One

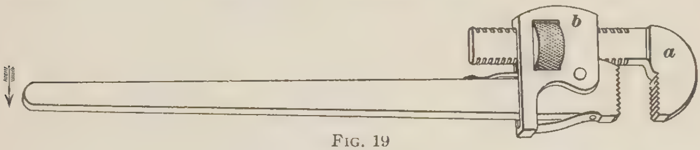


FIG. 19

side of this opening is left smooth and the other has teeth cut across it in the form shown in Fig. 20. These wrenches grip all round objects, and are used to grip pipe in places where the other forms of wrenches can get no hold at all.

22. Monkeywrench and Pipe Attachments.—In Fig. 21 are shown a monkeywrench and its attachments. The

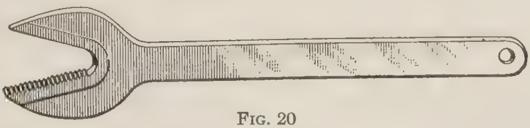


FIG. 20

wrench is adjustable and is much used in the machine shop. When in use, it is rotated in the direction of the arrow. A wedge-shaped piece of steel, or false jaw, having teeth cut on it similar to those on the jaw of an alligator wrench, may be made for any size of monkeywrench. When supplied with this

false jaw, the monkeywrench is used for pipe work. Such a jaw *b* is shown attached to the wrench in (*a*). This jaw is made with but one arm bent at a right angle, as shown in (*b*),

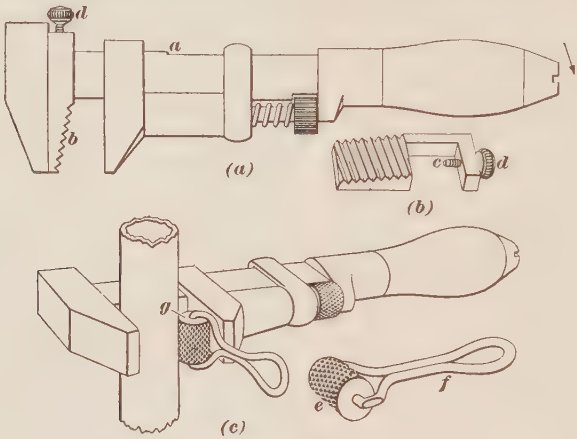


FIG. 21

to pass over the back of the bar. A thumbscrew *d* is used to hold the jaw on the bar. Instead of the form of false jaw just described, one made in the form of a fork whose two arms reach past the bar *a* in (*a*), of the wrench may be used. A hole is drilled through the ends of this jaw, so that a split pin can be

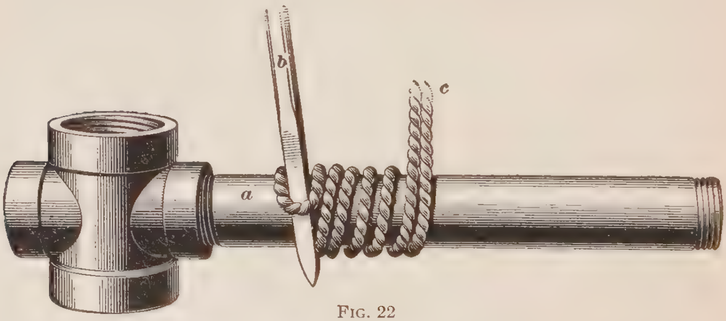


FIG. 22

put through them to keep the jaw from falling from its place on the bar. Another simple attachment for adapting a monkeywrench to pipework is shown in (*c*). This device consists of a

nurled and hardened cylinder, or roller, *e*, having a wire handle *f* for convenience in putting it in place. It is set between the wrench jaw and the pipe, or other round piece, as shown at *g*. A piece of a 10- or 12-inch round file about 1 or $1\frac{1}{2}$ inches long may be used instead of this attachment.

23. Use of Rope as Pipe Wrench.—A rope may be used in place of a pipe wrench in the manner shown in Fig. 22. The rope is first doubled, as shown at *a*, and given enough turns round the pipe to insure gripping. A bar or a piece of wood *b* is thrust through the double end of the rope *a*, and the two loose ends *c* of the rope are brought together and held with one hand while the other hand is applied to the bar. Enough strain is put on *c* to prevent slipping, and the pipe is turned by the bar *b*, the same as with any pipe wrench. The

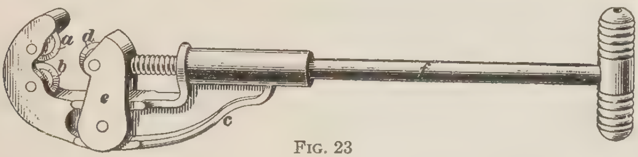


FIG. 23

workman may walk around the pipe, or by slacking off on both the bar and the rope ends, he may rotate the rope backwards to get a new hold.

24. Pipe Cutter.—Large pipe is generally cut into the proper lengths in a pipe-cutting machine by a cutting-off tool, in the same manner as stock is cut off in the lathe, and afterwards is threaded in the same machine. Some pipe machines are driven by hand, others by power. A great deal of small pipe is cut with a pipe cutter, shown in Fig. 23. The body *c* of this tool carries a slide *e*, operated by the screw on the handle *f*. Three hardened-steel cutting wheels *a*, *b*, *d* are set in the frame and slide. The slide *e* is drawn back by means of the screw, to allow the pipe to pass between the cutters, which are then forced into the pipe by turning the handle *f*, and at the same time rotating the tool around the pipe. Other cutters of this sort have but one cutting wheel, which is in the slide. In this case the wheels *a* and *b* are replaced by

cylindrical rollers and the wheel *d* by a narrow cutting-off tool. A hack saw makes a good pipe cutter, if employed carefully, and when blades having 25 teeth per inch are used, there is little danger of breakage. Thin brass and copper tubing can be cut more easily by a hack saw than by any other means.

VISES

25. Purpose of Vises.—In the machine shop a large amount of work is necessarily done by hand, and holding and clamping devices of various sorts are required for pieces that are not so heavy that their own weight will give them the necessary stability. The *parallel jaw vise* will hold nearly all flat pieces, and special jaws or devices are made for holding irregular and special forms.

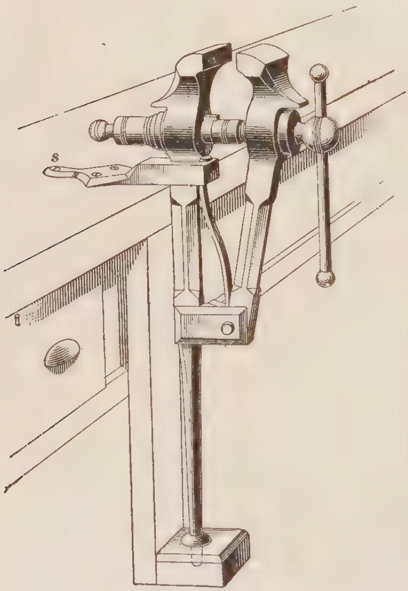


FIG. 24

26. Screw Vise.—In Fig. 24 is illustrated a heavy form of ironworker's vise designed for the largest, heaviest, and roughest class of work. The jaws are made as large as 8 inches wide and are operated by the screw, which requires considerable time for its manipulation. The body is secured to the bench with bolts that pass through the strap *s*. Where a vise must be operated frequently or through a considerable portion of its jaw traverse, some special provision for a more rapid traverse of the jaw must be made.

27. Rapid-Motion Vise.—In Fig. 25 is an illustration of a vise so constructed that the operator simply pushes the

cam handle a away from him with his right hand, and thus releases the work and allows the movable jaw b to be rapidly pushed or pulled into any position. The work is placed between the jaws and gripped by a pull on the lever.

28. Swivel Vise.—In the tool room and in many places where light or fine work is done, a screw vise like that shown in Fig. 26 is frequently used. This vise is made in various sizes up to those with 7-inch jaws. A common size of this form is one with a jaw $2\frac{5}{8}$ inches wide. The back jaw a is hinged and held parallel with the front jaw by a taper pin b, as shown. Wedge-shaped pieces must often be held and for this work the pin b is removed and the pressure of the fixed jaw against the work rotates the movable jaw to conform to the piece held. This vise is also provided with a base piece c, which is bolted fast to the bench. The vise proper is swiveled on this base and held in different positions by the pin d, which is drawn up to release the vise and dropped into one of a series of holes in the base when the vise is in the proper position.

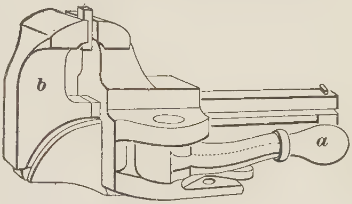


FIG. 25

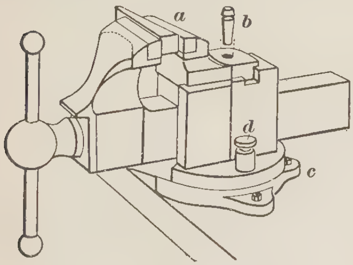


FIG. 26

29. Pipe Vise.—The pipe vise is a special form of tool made for firmly gripping pipe or other hollow pieces that would be crushed if gripped in the ordinary vise. Fig. 27 illustrates one of the best forms of vise for this class of work. The pipe is gripped between two jaws a, a' held in a malleable-iron frame with a movable top d hinged at e. When in use, the free side of the top d is held in place by the pin f. The hinged top on this vise allows fittings to be screwed to both ends of a piece of pipe, and then, by simply withdrawing the pin f, the whole top of the vise

may be thrown back clear of the work, which can be lifted out instead of being pulled through the jaws.

30. Pipe, being round, cannot be screwed together by the ordinary forms of wrenches, and, being hollow, it cannot be held in the ordinary vise without being crushed. For cutting, threading, or having fittings screwed on it, pipe may be held in the pipe vise just described, or in an ordinary vise having clamps made in the form shown in Fig. 28. The holes *a* in this clamp are made to fit the outside diameter of the pipe, and have teeth cut in them to prevent the work from slipping. They are held together by the spring *b*. For putting polished pipe together, some form of clamp or wrench having smooth jaws must be used.

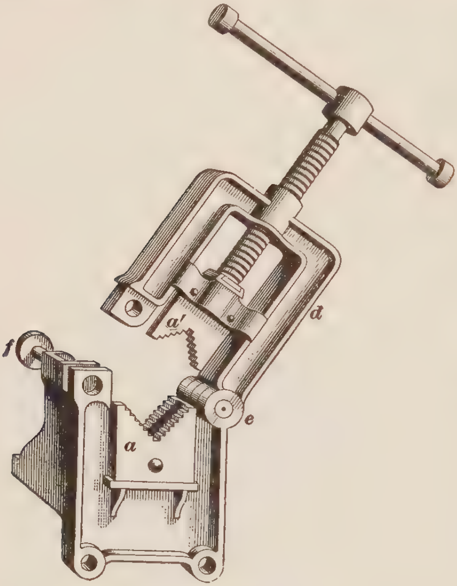


FIG. 27

31. Vise Jaws.—All the vises illustrated are made of cast iron, except the pipe vise, which is made of malleable iron.

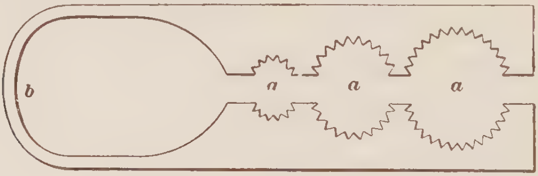


FIG. 28

These materials make poor gripping surfaces, so the jaws are covered with welded or riveted steel faces having cross-cuts on

them, in order to grip the work more firmly. A piece of finished work gripped with the surfaced jaws would be seriously marred. In Fig. 29 is shown a pair of soft-metal vise jaws made to fit over the steel jaws of the vise. When finished work is gripped between these jaws it is not marred. They are usually made of sheet copper from $\frac{1}{32}$ to $\frac{1}{16}$ inch thick.

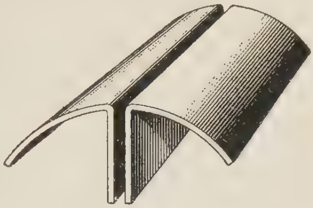


Fig. 29

Special jaws having cylindrical or irregular recesses cut in them to receive special work are sometimes used. When these jaws are faced with vulcanized

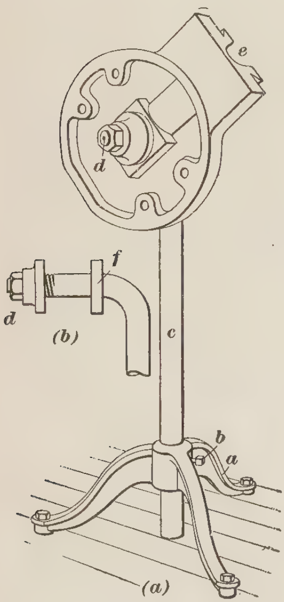


Fig. 30

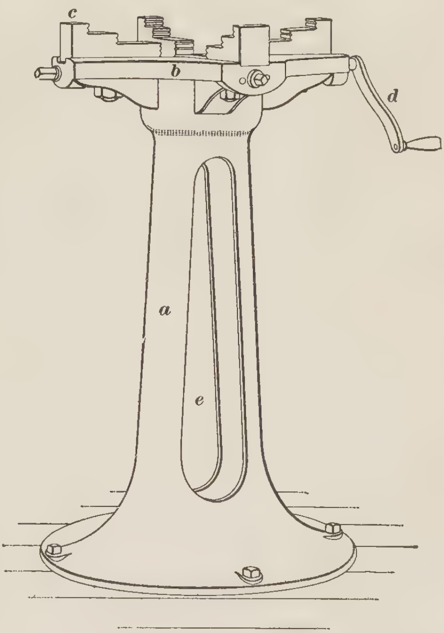


Fig. 31

paper or leather, finely polished brass or nickeled pipe and similar work may be held without marring the finish.

32. Special forms of vises are often made for holding work of such form as is inconvenient to hold in the common vise.

An example of this class of tool is the **filing stand** shown in Fig. 30 (*a*), which is a fixture for holding the swivel slide of a planer head while the edges are being finished. This vise, or holder, consists of a three-legged base *a*, screwed to the floor, and an upright *c*, supported by the base, that may be clamped in any desired position by the setscrew *b*. The top of the upright is bent at right angles to *c* and threaded for the nut *d*, which clamps the work *e* against the solid collar *f*, as shown in the detail view (*b*).

33. The **reaming stand,** Fig. 31, is another form of special vise, consisting of an upright *a* and a top *b*, which carries four jaws *c* operated by the handle *d*. This stand is bolted to the floor and has an opening *e* in the column, so that tools may be run clear through the work and removed at the bottom. Pulleys, gears, and similar pieces may be held for hand reaming and work may also be held for tapping. A similar and, for some purposes, more convenient form of reaming stand is made by fastening a four-jaw combination or universal chuck on an upright. The universal chuck has the advantage that for many small pieces only one screw need be moved to open or close the jaws.

BENCHES

34. Forms of Benches.—A very important part of the equipment of a shop consists of the benches, especially where a large amount of light work is done. They are usually made from 30 to 36 inches high, depending on the character of the work, the lighter work being done on the higher benches.

The forms of benches vary greatly, some being made stationary and others portable. The bench must, however, always have provision for attaching a vise, without which a machinist's work bench is incomplete. For this reason they are frequently called *vise benches*.

35. General Arrangement of Benches.—The vise bench should be located along the side of the room having the best light. The north side of the building is the best location for the bench, because the light is more even at all hours of the

day. The main features of the bench must, of course, be governed by the work to be done; but it should always be convenient, clean, and rigid. In many shops the bench is made with wooden uprights fastened to both the wall and the floor, and a hardwood top, which is 2 inches thick for a bench for light work, and from 3 to 4 inches thick for a bench for heavy work. The front of the bench gets the hardest usage, and the back half of the top may be made much thinner. Vises suitable for the work to be done should be located at convenient

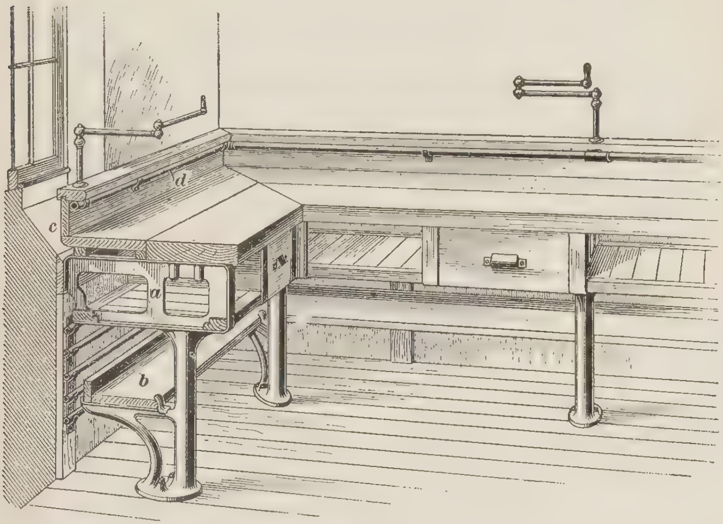


Fig. 32

distances apart, and for each vise there should be one or more drawers, each provided with a lock and arranged to hold conveniently such tools as the workman may require. Sometimes a tier of drawers is put in instead of the single one, while at other times cupboards are preferred. Cupboards, however, take up much room and hold conparatively little, and for this reason the drawers are usually more desirable.

36. Bench With Cast-Iron Legs and Frame.—The best form of bench for general use is that illustrated in Fig. 32. A cast support *a* is bolted to the floor and also to the wall.

The lower part has a bracket for carrying a shelf *b* that extends the whole length of the bench, while provision is made under the

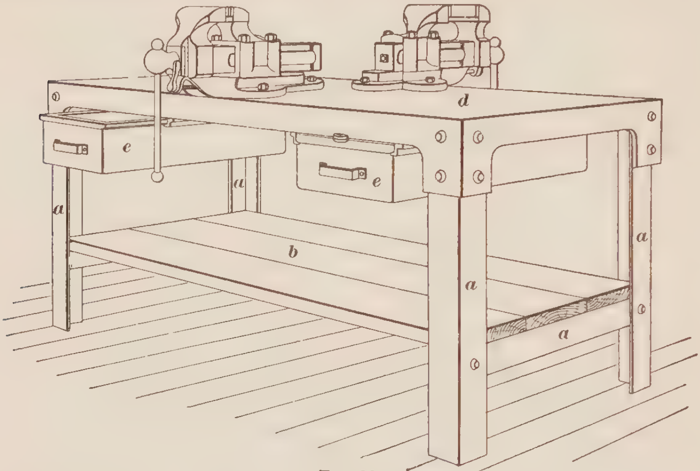


FIG. 33

top for alternate drawers and shelves. Provision is also made in each support by which the bolt holding the vise passes

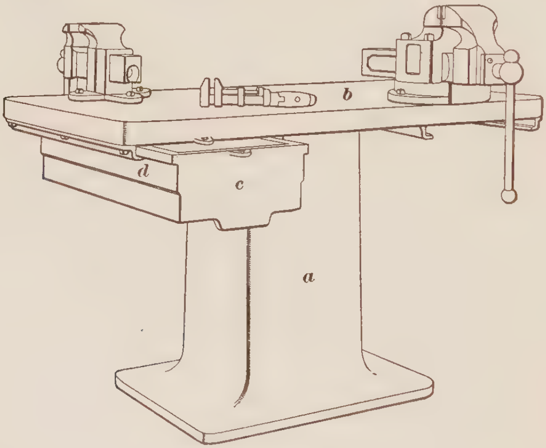


FIG. 34

through the casting and thus secures the vise in the most rigid position. The shelf near the bottom allows ample room for

the sweeper to get his broom clear to the wall. The top of the bench should have a smooth finish and all the visible woodwork should be varnished with good shellac. The bench is thus made much easier to keep neat and clean. If the shop is heated by steam, the pipes may be placed under the bench and openings *c* provided before the windows. This insures a rising current of warm air past the window and so protects the workman from cold drafts. In the form shown, a gas pipe *d* extends along the back of the bench. When the shop is lighted by electricity, the gas pipe is replaced by an electric conduit.

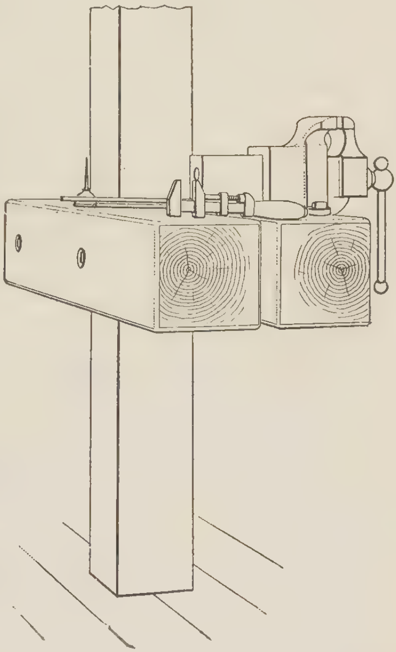


FIG. 35

37. Portable Benches. Examples of good types of portable benches are shown in Figs. 33 and 34. The larger of these, Fig. 33, consists of angle-iron legs *a* carrying a wooden shelf *b* and a cast-iron top *d* that may be planed true and used as a laying-out table. The bench is provided with two vises and drawers *e*, for tools. This bench may be moved to the work, instead of taking the work to the bench, which makes it especially useful in large shops where heavy machinery is erected. When engines or other machines are shipped, the bench is often loaded on the cars as one of the erecting tools, and is returned to the shop when the work is finished.

The bench illustrated in Fig. 34 consists of a cast-iron column *a* and a cast-iron top *b* provided with two vises. The bench may be used without the vises for a small laying-out table. A cast drawer *c* held by gibs *d* provides a convenient

place for the tools used by the workman. This bench is easily moved to any part of the shop and occupies but little space.

38. Post Bench.—Fig. 35 shows a convenient form of bench that may easily be constructed from two pieces of timber cut to fit a post or column and fastened in position with two bolts. It is useful principally as a vise bench, as shown, but may be used for a variety of purposes.

CHIPPING AND FILING

CHIPPING

39. Forms of Chisels.—The forms of chisels most commonly used in the machine shop are the *flat*, *cape*, *diamond*, *grooving*, and *side* chisels, and the *gouge*. They are generally made from octagon steel of the size most convenient for the work for which they are to be used. Special grades of steel, known as *chisel steel* and containing about 1 per cent. of carbon, are made for chisels.

The proper cutting angle for most chisels is the same as that for the flat chisel for metals of the same grade, the angles for different grades of metal varying from 50° to 75°. The softer the metal, the sharper the cutting angle of the chisel should be.

When cold chisels are used in the pneumatic hammer, the shanks must be fitted to the holder in the hammer, either by turning or milling, and the head should be carefully tempered to prevent its being upset in the socket of the machine. The chisels used in the pneumatic machine should be longer than those used by hand.

40. The **flat chisel** is the one most generally used; it is made in the forms shown in Fig. 36 (*a*), (*b*), and (*c*). The width of the cutting edge should, if possible, be proportioned to the hardness of the metal on which it is to be used, a narrow chisel being used for chipping the harder metals. If one width of chisel must answer for brass, cast iron, steel, and Babbitt, lighter blows should be struck while cutting the softer metals,

or the metal will be broken rather than cut off by the chisel. A chisel about 1 inch in width is ordinarily used for general purposes.

41. For finishing surfaces, the edge of the flat chisel should be ground square, as shown in Fig. 36 (*a*), the best angle for

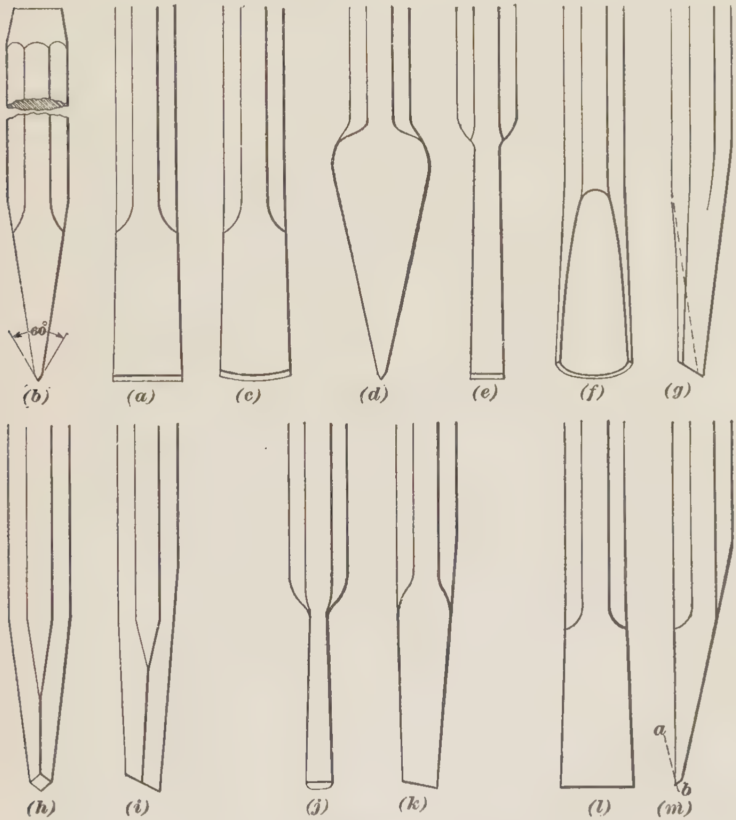


Fig. 36

ordinary work being about 60°, as shown in (*b*). This angle may, however, vary between about 50° and 75°, depending on the hardness of the material to be chipped, the blunter angle being used for the harder metals. Chisels ground with square corners, as illustrated in (*a*), are likely to have the corners broken

when used for heavy work; but this can be sometimes prevented by grinding the chisel slightly rounding, as shown in (*c*).

42. The **cape chisel,** which is shown in Fig. 36 (*d*) and (*e*), is used for making narrow grooves, and is manufactured in widths to correspond to the widths of the grooves to be cut; for general work it may be from $\frac{3}{8}$ to $\frac{1}{2}$ inch wide. This chisel should be made wider at the cutting edge than it is farther back, to provide side clearance. The chisel will then work easier and will not break out the edges of the groove. Where a large surface is to be finished by chipping, it is customary to cut a number of grooves across it with the cape chisel and then use a flat chisel to remove the stock left between the grooves.

43. The **half-round gouge,** shown in Fig. 36 (*f*) and (*g*), is for work on rounded surfaces or fillets, or for cutting half-round grooves.

44. The **diamond-point chisel,** shown in Fig. 36 (*h*) and (*i*), is used for **V**-shaped grooves or for finishing out corners. It is largely used with a very light hammer in lettering bottle molds, for which use it is made of $\frac{3}{8}$-inch steel.

45. The **grooving chisel,** Fig. 36 (*j*) and (*k*), is used for chipping oil grooves and similar work, and is often made of extra length to reach through long hubs. This chisel should be made wider at its cutting edge than it is farther back, as in the case of the cape chisel; otherwise, it may leave a burr on the edges of the groove.

46. The **side chisel,** shown in Fig. 36 (*l*) and (*m*), is used for finishing the sides of slots and similar work. The chisel is ground straight on the side next to the work, if it is to be used in deep holes; for shallow holes it is best to give it a slight angle, as indicated by the line *a b*, (*m*), and to allow the body of the chisel to stand at a greater angle to the work while being used.

47. Methods of Chipping.—*Chipping* is the process of removing stock by means of the hammer and chisel. It corresponds to the roughing cut in machine tool work, and the filing that follows it takes the place of the finishing cut.

There are two methods of chipping—the *hand* and the *pneumatic*. The process is applied both to the roughest and coarsest work, and to some of the finest work that comes to the machinist. It is used in the machine shop, foundry, and smith shop, and chisels of various sorts form an important part of the outfit of the erecting gang.

48. Holding Hammer and Chisel.—For ordinary chipping, a hammer weighing from 1 to $1\frac{3}{4}$ pounds, and a

FIG. 37

variety of chisels, the most common of which are the flat, cape, gouge, and various forms of side and grooving chisels, are used. When chipping, the hammer is held in the right hand, as shown in Fig. 37, and is grasped by the thumb and second and third fingers, the first and fourth fingers being closed loosely around it. The hammer handle may thus be swung more steadily and more freely without tiring the hand so much as if the handle were grasped rigidly by all four fingers.

49. The chisel should be grasped in the left hand with the head close to the thumb and first finger, and held firmly with the second and third fingers; the little finger may be used to guide the tool as may be required. The first finger and the thumb should be left slack, as they are then in a state of rest, with the muscles relaxed, and are less liable to be injured if struck with the hammer than if they were closed rigidly about the chisel. The point of the chisel is held on the work, as shown in Fig. 37, at the place where it is desired to take the cut, and at an angle that will cause the cutting edge to follow the desired finished surface. After each blow the chisel is set to the proper position for the next cut. The depth of the cut depends on the angle at which the chisel is held to the work. When the angle

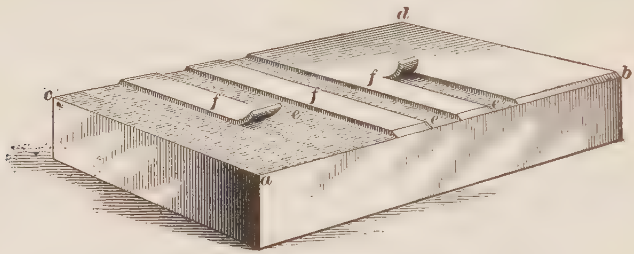


FIG. 38

between the work and the chisel is increased, the chisel will cut deeper and when decreased the chisel will remove less metal.

50. Chipping Large Flat Surfaces.—Large surfaces, whether flat or curved, are sometimes finished by chipping. The piece is laid out as shown in Fig. 38, the lines *a b*, *a c*, etc. outlining the edges of the required surface. To facilitate the starting of the chisel and to prevent the breaking off of the stock as the chisel leaves the work, it is well to chamfer the front and back edges, as shown at *a b* and *c d*. The stock above the lines *a b*, *c d*, etc. is removed by first cutting grooves *e* across the surface, leaving the ridges *f* between. These ridges are subsequently removed with a flat chisel. In the illustration, the left-hand ridge has all been removed and half of the one next to it. By cutting the grooves across with the cape chisel, the work of the flat chisel is much reduced, as it is used only for

straight cutting with no tearing or lifting of the metal at the corners. The width of the ridges *f* is determined by the width of the flat chisel to be employed, and should be as great as the character of the material being cut will permit.

51. Chipping Strip.—The castings for many kinds of work are frequently fitted by chipping and filing. Work of this class has what is called a chipping strip on the casting

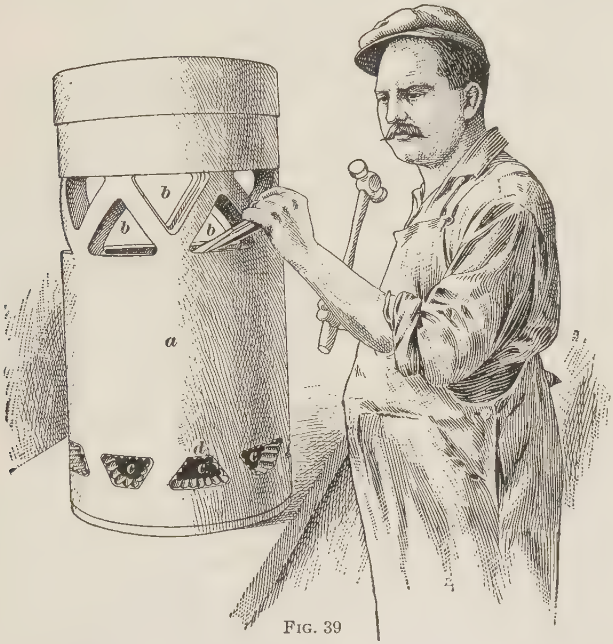
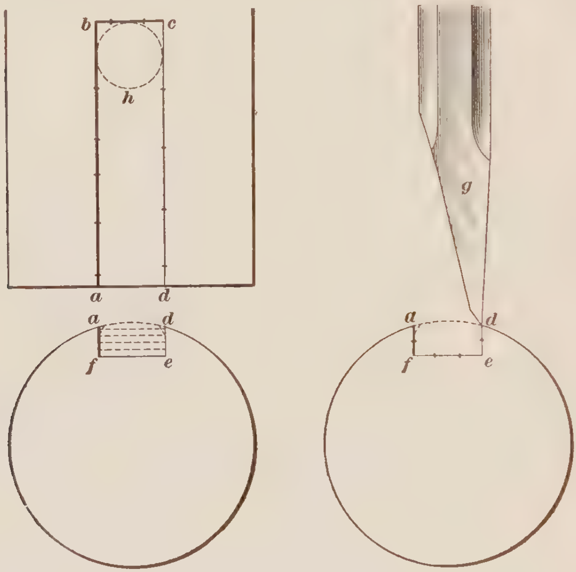


FIG. 39

wherever fitting is to be done. This strip is $\frac{1}{8}$ inch or more higher than the body of the casting, and wide enough to make the joint or fit. Castings to be fitted by this process are put together and their high spots noted, chalked, and chipped off. As the work progresses and the heavier parts are removed, red marking is rubbed on the work, and the parts are tried or rubbed together. The coating of red will be rubbed off on the spots that come in contact with the other part, thus showing more plainly where the chipping must be done. When

the parts have been chipped to fit approximately, they are finally finished by filing.

52. Chipping Piston-Valve Bushing.—Fig. 39 is an illustration of a class of work which is frequently finished by chipping. In the figure *a* represents the bushing of a piston valve in which two series of ports *b* and *c* must be cut out of the solid metal. The ports are laid out in the usual way, the outline *d* being clearly marked on the surface. The bushing



(a) FIG. 40 (b)

is then taken to the drilling machine and the ports are drilled out, just enough stock being left outside of the drill holes to insure a good finish. The holes may be drilled so close together that when the drilling is finished the block of metal may easily be removed by a blow with the hammer. The ridges between the drill holes are chipped away, as shown in the illustration, and the sides of the ports are finally finished to the lines by filing.

53. Chipping Keyways.—The keyway is first laid out as shown by the lines *a b*, *c d*, *e f*, Fig. 40 (*a*). The lines are

sometimes marked with a prick punch, as shown. The side lines *a b* and *c d* of the keyway should be marked with a deep chisel cut, as shown at *a* and *d* in the end view, to prevent the material from tearing out along the sides of the keyway during the first cut with the chisel. This cut is best if made with a side chisel *g*, in (*b*), that is ground and held as shown in the figure. An ordinary flat chisel may be used for this work, if ground to a rather sharp angle and held so as to bring one of its cutting sides square with the side line *d*.

54. A cape chisel of proper width is used to remove the stock, several light cuts being driven through the keyway as indicated by the dotted lines in Fig. 40 (*a*). The keyway, if long or at the end of the shaft, may be finished by filing;

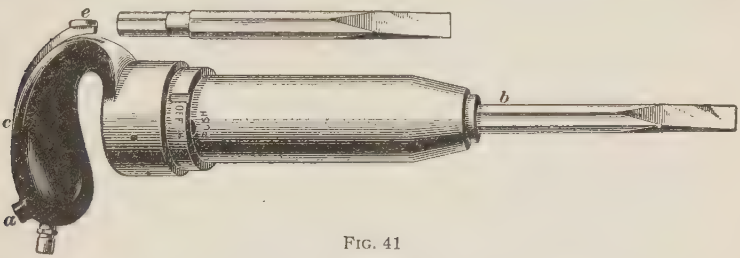


FIG. 41

but when it is in the middle of the shaft the finishing must be done with chisels.

When it is considered easier to drill out the stock before chipping, a line of holes like that marked *h* is laid out and drilled to the right depth, the bottoms squared with a square-end drill, and the remaining stock chipped to the lines. This method is especially applicable to large keyways.

55. Keyways in pulleys and gears are often chipped in. They are first laid out on both ends of the hub and lines drawn through the bore. If the keyway is a narrow one, a chisel of corresponding width is used, and the cut driven from each end; but if it is wide two or more narrow parallel grooves are chipped through and the stock between is removed with a flat chisel.

56. Pneumatic Chipping Hammer.—The pneumatic chipping hammer, illustrated in Fig. 41, is sometimes used for

chipping, and has some advantages over the hand method. It is supplied with air at a pressure of about 80 pounds per square inch, through a small hose connected to the hammer at *a*. The operator holds the chisel *b*, which has a hexagonal shank fitting a similarly shaped socket in the device, in his left hand, as in ordinary chipping, and the device by the handle *c* in his right hand, with the thumb on the trigger *e*. Heavy or light blows may be struck, as the operator desires, by regulating the pressure of the thumb upon the trigger. The whole is held firmly in position against the work, and light pressure applied to the trigger to start the chisel into the metal. As soon as the cut is started, more air may be admitted to the tool, making it strike harder and faster. The blows struck by this hammer are so rapid that the chisel has almost a continuous cutting motion.

Pneumatic hammers of this type are used for many purposes; some of them have round instead of hexagonal bushings for holding the chisel. The chisels are not gripped in the device. For this reason the round-shanked chisel must be guided by the left hand. The chisel with the hexagonal shank is easily directed by the handle *c*.

FILING

57. Use of Files.—In finishing machine parts, there are many cases where a smaller reduction in size or a more perfect surface is required than can be obtained by the use of machine tools or by chipping. For both of these purposes great accuracy can be obtained by the careful and skilful use of files. In order to smooth a rough surface, files of various degrees of fineness are employed, a coarse one first, followed successively by finer grades, the piece being finished with the finest. A file is made of a piece of steel of the desired shape and size, and has a series of grooves cut across its face. When a file is passed over the surface of a body of metal or other material, the teeth formed by the grooves act on it as a series of small chisels or cutters, each removing a tiny chip. By passing the file across the surface successively, the high parts are removed. Each file, however, leaves its own marks, and these are removed, if desired, by means of the finer grades of files.

58. Chattering When Filing.—Files were first cut with regularly spaced teeth; but this method was found objectionable, because, in filing, the teeth follow each other at regular intervals and drop into the cuts made by the preceding ones, causing chattering. Hand-cut files are more satisfactory, as the slight irregularity in the spacing prevents chattering. This difficulty in machine-cut files was overcome by gradually increasing the spaces between the teeth from the end of the file to the middle, and again decreasing as the other end is approached. In this way, enough variation is produced to prevent the chattering, without causing enough change from the true spacing to affect the working conditions. By this method of cutting, called the *increment cut*, the two ends of the file are of the same coarseness, while the middle is somewhat coarser.

Files are also cut with the gradations of spacing running from end to end, the spacing being finer at the point and increasing gradually to the shoulder, thus accomplishing practically the same result as in the style just mentioned. This is also known as an increment cut.

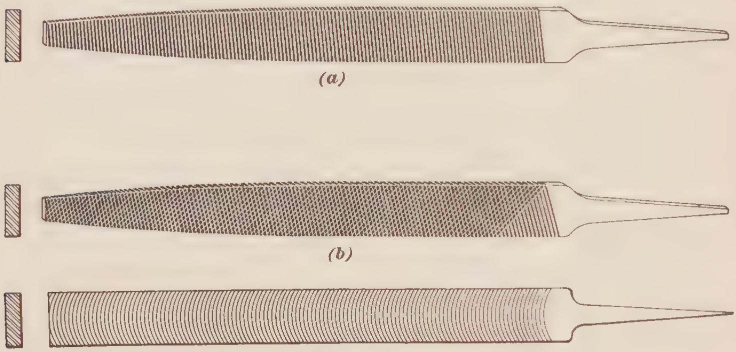
59. Chattering is also prevented by cutting the teeth slightly out of parallel. By changing the direction of the deflection several times in the length of the file, enough variation may be obtained to avoid chattering. Files cut in this way are largely used at the present time. By varying the angle of the motion of the file gradually during the forward stroke, when there is a tendency to chatter, the regularly spaced file will work smoothly and well; hence, this style of file is still in use.

60. Forms of File Teeth.—The teeth of files are not generally cut at right angles to the sides of the file, but either at an angle or in a curve. The angle or curve varies for different materials. Most files used in machine shops are cut in one of three different ways, and are known as the *single-cut*, *double-cut* and *circular-cut files*. In Fig. 42 (*a*) is shown a single-cut, in (*b*) a double-cut, and in (*c*) a circular-cut file.

61. Single-cut files are cut with a single series of teeth running continuously from one end of the file to the other, as

illustrated in Fig. 42 (*a*). They are used almost entirely for filing in lathes, and for filing the softer materials, such as lead, wood, horn, etc.

62. By making another cut, at an angle to the first, or over cut, a file is produced as shown in Fig. 42 (*b*), and is called a **double-cut file.** The second, or up cut, is generally cut a little finer and not as deeply as the over cut. The angles that the two cuts make with the axis of the file vary for different uses, the over cut ranging from 35° to 55°, and the up cut from 75° to 85°. The up cut has the effect of dividing the



(*a*)

(*b*)

(*c*)

FIG. 42

small cutting edges produced by the over cut into a large number of small pointed teeth. Files thus made in various grades of coarseness give excellent results.

63. The shape and depth of the teeth of the **circular-cut file** resemble in section those of a milling cutter. The teeth of these files have an included angle of 60°, a front rake of $1\frac{1}{2}$°, and a radius of $1\frac{1}{4}$ to $1\frac{1}{2}$ inches. They are not increment-cut, as are the single- and double-cut files; consequently, when filing the angle at which the file is held to the work must be varied slightly throughout the stroke. A rather large chip is removed with light pressure, and the form of the tooth permits the chip to free itself. These files are used principally when considerable metal is to be removed, and also for lathe and finishing

filing. On account of the large teeth used in this type of file, they are readily sharpened by grinding, as explained later.

64. Grading of Files.—Table I gives the classification of ordinary American files as to grading and their equivalent in circular-cut, English, and Swiss files.

The coarse and bastard cuts are used almost entirely on the coarser grades of work, and the second cut and smooth are employed in finishing and for the finer classes of work. The rough and dead smooth are rarely used in the machine shop, although occasionally a rough single-cut file may be required for work in lead or other soft material. The dead-smooth double-cut file is occasionally used on extremely fine work. The

TABLE I

GRADING OF FILES

Ordinary American	Circular Cut	English	Swiss
Rough		Rough	
Coarse		Middle	
Bastard	Regular	Bastard	00
Second cut	Fine	Second cut	1
Smooth	Smooth	Smooth	2
Dead smooth	Dead smooth	Superfine	3

coarseness of the cut for each grade varies with the size of file, the cut being coarser on the larger files. Fig. 43 illustrates the comparative coarseness of 4-inch and 16-inch files, (*a*), (*b*), (*c*), and (*d*) showing the single-cut, rough, coarse, bastard, and second-cut files; (*e*), (*f*), (*g*), and (*h*) the double-cut, coarse, bastard, second-cut, and smooth files; and (*i*), (*j*), (*k*), and (*l*) the circular-cut, regular-fine, smooth, and dead-smooth files.

65. Sizes of Files.—The size of a file is generally indicated by giving the length in inches of the cut part, the tang not being included. Thus, a 10-inch bastard flat file means a bastard flat file 10 inches long from the point of the file to the tang.

66. Shapes of Files.—Files are divided into three general classes with regard to their cross-sections, as *quadrangular*, *circu-*

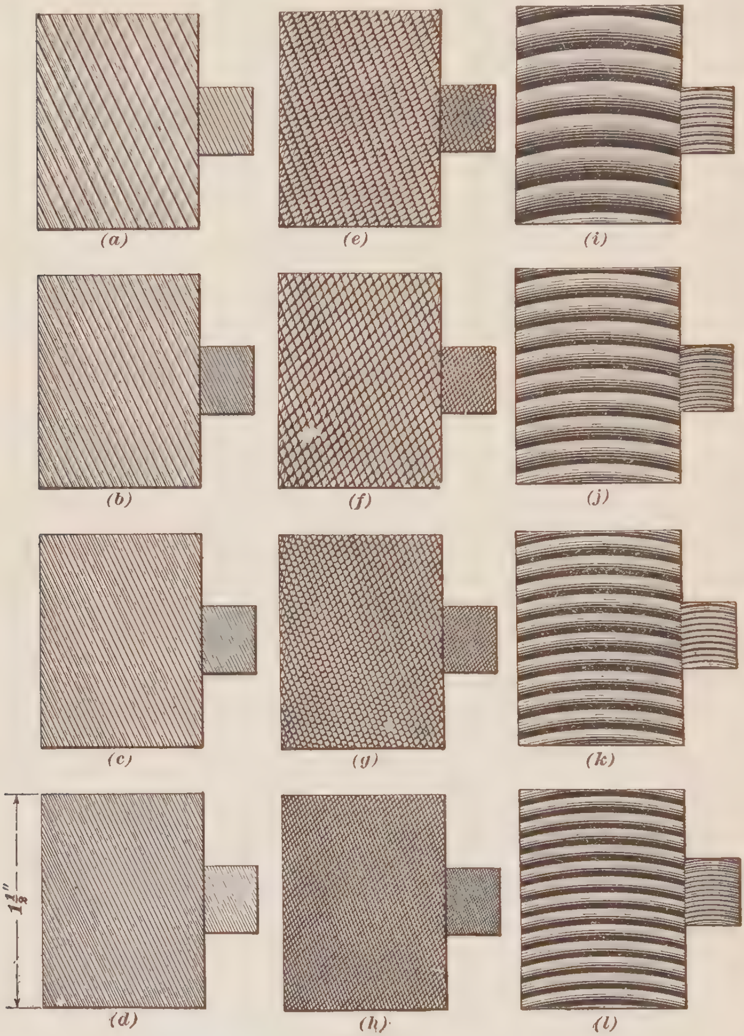


Fig. 43

lar, and *triangular*. These classes of files are further sub-divided into *blunt*, *equaling*, *taper*, *hand*, and *safe-edge*, or *side*, *files*.

67. A **blunt file,** Fig. 44 (*a*) has straight sides and the same width and thickness throughout. An **equaling file** is a blunt file whose edges have an exceedingly slight curvature, extending from point to the tang. A **taper file** is one whose sides are tapered, as shown in (*b*). The same name is also given to the three-cornered or triangular, hand-saw file. A **hand file** is one having its sides parallel and its thickness from point to tang tapering. A **safe-edge,** or **side, file,** has one or more of its edges or sides smooth or uncut, that it may not injure that portion of the work which does not need to be filed.

68. Table II gives the characteristics and uses of the files commonly used in the machine shop. The degree of coarseness

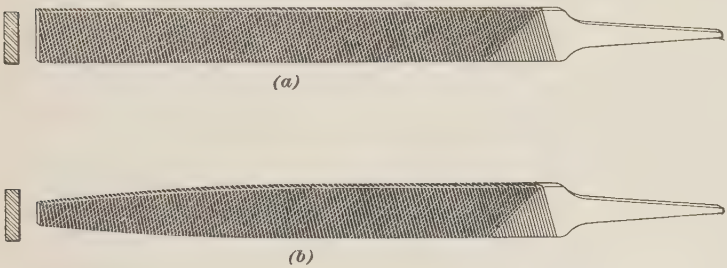


FIG. 44

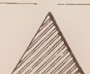
of cut given is that of the ordinary American file. The equivalent in grade of other types of files can be found by referring to Table I.

69. Purpose of Filing.—In machine construction many parts must be finished by hand. The part may have been finished as far as possible in a machine tool, but the surface could not be made sufficiently smooth; or it may be so located, or of such a character, that a machine tool cannot be used, and the entire work must be done by hand. In the latter case, the excess of metal may be removed with a cold chisel, and the work then finished by filing.

70. The operation of filing is one of the most difficult of machine-shop operations, and the quality of the work produced depends almost entirely on the skill of the workman. In most

TABLE II

CHARACTERISTICS AND USES OF FILES

Comparative Cross-Sections of Files	Name of File	Common Lengths Inches	Character of Cut	Coarseness of Cut	Shape	Use
 	Mill / Mill blunt / Round-edge mill	4 to 16	Single	Mostly bastard	Taper / Blunt / One or two round edges	For lathe work, draw-filing, and to some extent for finishing brass and bronze
	Equaling	6 to 12	Double	Mostly bastard	Blunt	For general machine-shop work. (Seldom called for)
	Flat / Flat blunt	4 to 16	Double / Circular	Mostly bastard; many second cut and smooth; some dead smooth	Taper / Blunt	Used by mechanics generally for a great variety of purposes—one of most common files in use
	Hand	4 to 16	Double / Circular	Mostly bastard; many second cut and smooth; some dead smooth	Parallel sides and tapered thickness	Preferred by machinists for finishing flat surfaces. Its shape and its having one safe edge make it particularly useful where the flat file cannot be used
	Pillar	6 to 14	Double / Circular	Mostly bastard; many second cut and smooth; some dead smooth	Parallel sides and tapered thickness	For general machine-shop use on narrow work
	Square	4 to 16	Double / Circular	Bastard	Taper	Almost all branches of mechanical work; principally for enlarging holes of rectangular shape
	Square blunt	10 to 20	Double / Circular	Bastard	Blunt	For the rougher work in finishing or enlarging mortises and keyways, when of considerable length
	Round / Rat tail, or mouse tail / Round blunt	4 to 16	Single (spiral)	Mostly bastard	Taper / Blunt	For enlarging round holes and for shaping the fillets on the internal angles
	Half-round / Half-round blunt	4 to 16	Double. Single on convex sides of grades finer than bastard / Circular	Mostly bastard; many second cut and smooth; some dead smooth	Taper / Blunt	Wide use in machine shops
	Three-cornered, or triangular	6 to 14	Double / Circular	Mostly bastard	Taper	For filing acute internal angles, clearing out square corners, filing up taps, cutters, etc.

machine-shop operations, the tool is guided by the machine, as in a planer, shaper, or milling machine. In hand filing, the accuracy of the work depends on the motion of the hands, with no means of guiding the tool.

71. Convexity of Face.—A convex file surface will produce the best results. The pressure of the hands on the two ends of the file tends to spring the file and make the lower face concave; also, when files are being hardened, they have a tendency to spring, thus making it impossible to produce files that have perfectly straight surfaces.

In filing wide surfaces, a perfectly straight file would require a very heavy pressure to make it take a cut; while the same file on a narrow surface would cut under a very light pressure. In the latter case, the pressure is concentrated on a few teeth; while in the former it is distributed over a large number, and consequently to secure enough pressure on each tooth to make it cut, a very heavy pressure is necessary. A light pressure with a small number of teeth in contact will produce the best results. By making the files convex, only a few teeth will be in contact at one time, however wide the surface may be. The faces of files are, therefore, made convex for three reasons: to overcome the effect of spring due to the pressure of the hands, to overcome the spring caused by hardening, and to make the file cut on any width of surface.

72. Fitting Wooden Handles.—File handles are made of wood with a ferrule on the end, and having a hole to receive the tang of the file. As the sizes of the tangs vary for the different forms and sizes of files, the hole must be small enough to receive the smallest file for which it is intended. If the handle is made of a soft wood, the larger tangs may be driven in without splitting it; but when made of hard wood, the hole may be burned to about the right size by using the heated tang of a worn-out file of the same size as the one being fitted. If no old file is available, the tang of the new file may be heated. A piece of wet waste should be wrapped about the file up to the tang, to prevent its temper from being drawn. The handle should be driven well up to the heel of the file.

73. Special File Handles.—In filing broad surfaces, as the tops of lathe beds, and in finishing long slots, the ordinary wooden handle cannot be used. Fig. 45 shows a good form of

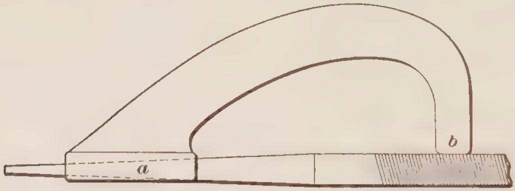


FIG. 45

handle. The end *a* is formed with a dovetailed slot that slips over the tang, while the point *b* rests upon the back of the file. The slot should be made to fit about the middle of the tang of a 12-inch file. The foot *a* should be about $1\frac{1}{2}$ inches long and the handle about $\frac{5}{8}$ inch in diamter.

74. Another handle that has some advantage over the one just described is shown in Fig. 46. A foot *a* rests upon the file and has a dovetailed slot that catches over the tang. A rod *b* has a lug *c* on its front end that catches over the point of the file. The handle *d* contains a nut that screws on the end of the rod *b*, and by means of which the file is held firmly between the catch *c* and the foot *a*. A column *e* at about the middle of the file makes the handle more rigid, and prevents the file from springing up in the middle when pressure is put upon it. A projection on the front end of the rod furnishes a convenient thumb rest.

75. Holding Files.—The right way to hold a file is learned as easily as a wrong one; but having once become accustomed to

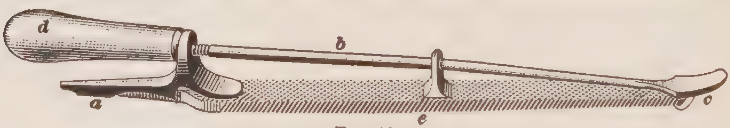


FIG. 46

the wrong, it is very hard to change to the right. There is some difference of opinion as to the correct way, but the following is considered good practice:

In moving the file endwise across the work, commonly called *cross-filing*, it is generally held as shown in Fig. 47 (*a*) and (*b*); for lighter work, and in finishing cuts, the former

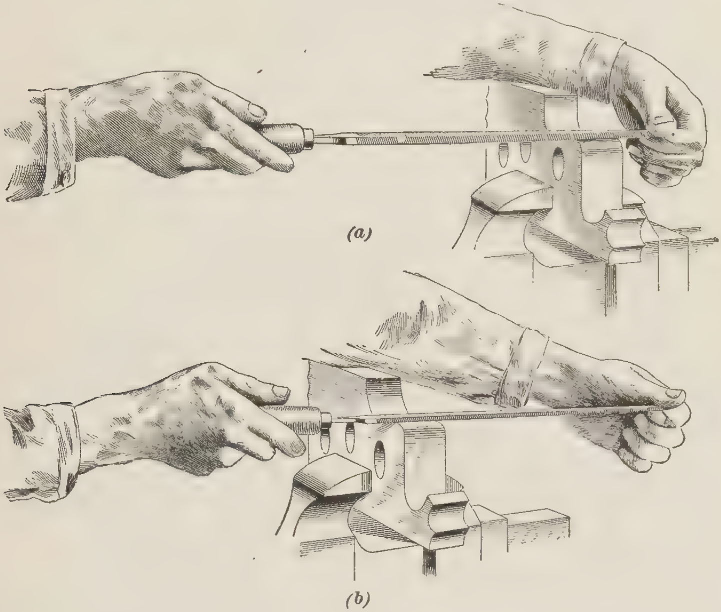


FIG. 47

illustration shows the relation of the hands to the file at the beginning of the stroke, and the latter at the end of the stroke. The point of the file is held between the thumb and the first finger, as shown in the two views, while the handle is held by

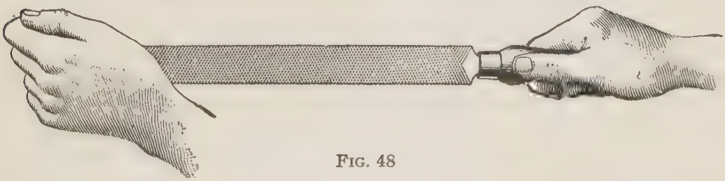


FIG. 48

resting the thumb upon it, as shown in these illustrations and in Fig. 48, and letting the end stand against the palm of the hand, the fingers gripping it lightly. When the work is heavy

and a large file is used, the ball of the left hand is placed on the point of the file, while the handle may be gripped as shown in Fig. 48. In the latter case the handle is gripped a little farther forwards than in the case of light work.

76. When the file is very thin, there is great danger of springing it so as to round the corners of the work. By holding it as shown in Fig. 49, a downward pressure is put upon both thumbs and an upward pressure upon the fingers of both hands.

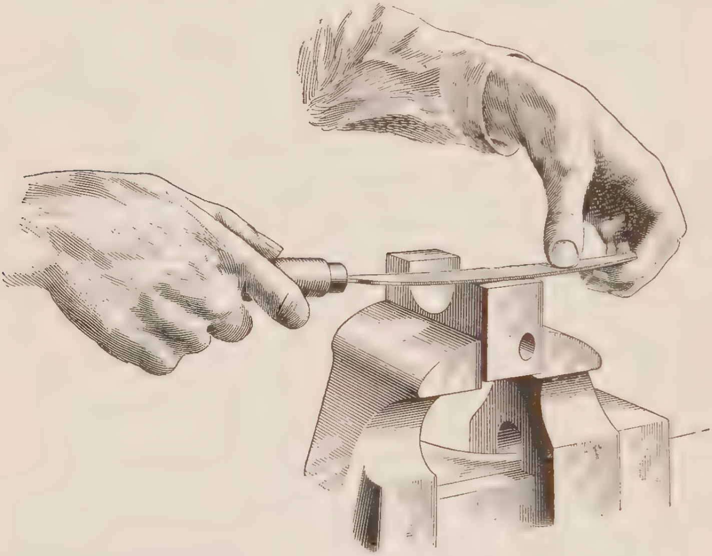


FIG. 49

This pressure is just sufficient to overcome the tendency of the ends to spring downwards. By making the pressure great enough to spring the file downwards considerably in the center, a concave surface may be formed in the work. It is very difficult, however, to hold a file in this way longer than a few minutes, and it is better to use a heavier file that has considerable convexity and stiffness, whenever that is possible. On very light files spherical handles are often used.

77. For internal work, when the hole is long, and it is impossible to hold the file at the point, a very great stress comes

on the wrist of the right hand, which soon becomes tired. This stress may be relieved by placing the left hand over the right, as shown in Fig. 50. When the work is thin, so that the

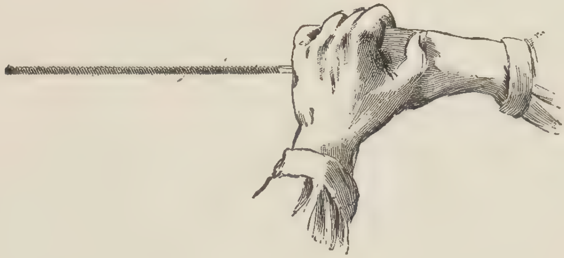


Fig. 50

file will reach through the work far enough to take hold of the point, the ordinary method of holding it for outside work is generally used. In draw-filing, the file is grasped at each side of the work, as shown in Fig. 51.

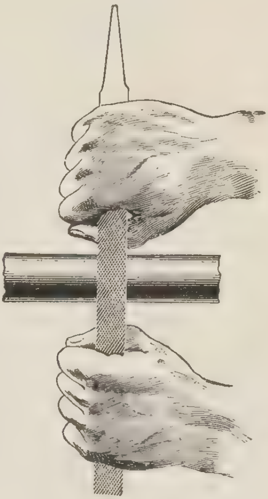


Fig. 51

78. Cross-Filing.—One of the most difficult, though most common, forms of filing is cross-filing. In moving the file back and forth, the hands tend to swing in arcs of circles about the joints of the arms, while the body sways more or less, depending on the work. To overcome these tendencies so as to move the file in straight lines requires a great deal of practice and careful observation of the results of certain movements. Filing on narrow work is especially difficult. The work becomes a fulcrum on which the file rests at different points along its course, and if an equal pressure is put on each end, it will tilt first one way, then another, depending on the point of contact and the leverage. For instance, in Fig. 52, when the file is in position *a*, there is a tendency for the handle to tilt downwards from the fulcrum *b*; when in the

position c, represented by the dotted lines, the point tilts downwards about the fulcrum d. As the file runs forwards, there is therefore a tendency to file off the corners more than the middle of the piece and to produce a convex surface. On wide work this tendency is lessened. By persistent care to have the file rest evenly on the work, this difficulty may be entirely overcome.

79. Filing Broad Surfaces.—There is little danger of rounding the corners in filing broad surfaces, but other difficulties present themselves. Files for this class of work have convex faces, and only a few teeth cut at a time. The strokes must then be so gauged that an equal cut is carried across the entire piece. If numerous short strokes are made they are liable to overlap each other at some places and not meet at others, and to wear out the files at the middle while the ends are still good. Uniform strokes of as great a length as possible should be made.

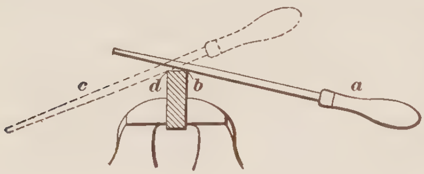


FIG. 52

When high spots are to be removed, the file must be so held that the teeth over these spots are in contact with the work. By commencing the stroke with the teeth near the point in contact, and lowering the handle gradually to compensate for the convexity, the effective work of the whole stroke may be concentrated on a small area. On the other hand, care must be taken that this is not done when the metal is to be removed evenly from a broad surface, or a concave or irregular surface will be the result. The file should move perfectly parallel to the work, or be gradually tilted so as to increase the length of the cut.

80. Diagonal Filing.—Small grooves are left on the work at each stroke in filing, and when the strokes are all made in the same direction these grooves become deeper; this increases the work to be done, because these marks must be removed by means of finer files. By changing the angle of the direction

of the stroke with the work, at short intervals, this difficulty may be avoided. The file will also cut more freely, as the grooves run at an angle to the cut and the particles are separated more easily. The workman can see where the file is cutting and gauge the stroke so that the desired part of the surface will be removed.

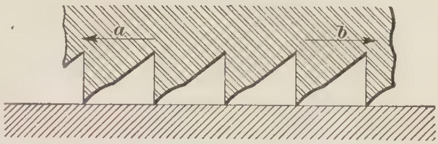


FIG. 53

Changing the course of the file as described above is often called *diagonal filing*. The angle that the strokes should make with each other depends on the work. Practice alone will enable one to determine what this angle should be.

81. Pressure on File.—In all kinds of filing there should be just enough pressure put on the file during the forward stroke to make it cut freely; but no pressure should be put on it during the return stroke. The teeth of a file are formed approximately as shown enlarged in Fig. 53. When pressure is put on the file and it is moved in the direction of the arrow a, the cutting edges are well supported and the angle of the cutting face and the clearance produce very good cutting conditions. When moving in the direction of the arrow b, which corresponds to the return stroke, these conditions are reversed. The angles are such that the teeth will simply drag over the work, without cutting, while the edges are poorly supported and any pressure put on the file will cause the teeth to break or wear away very rapidly without doing any work.

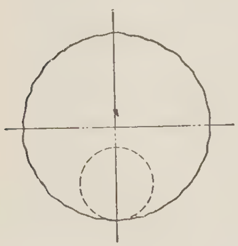


FIG. 54

82. Filing Curves.—In filing circular holes, a round file that is as nearly the size of the hole as it is possible to obtain should be used. A small file will tend to produce the ridges shown in Fig. 54; with a larger file that conforms more nearly to the curvature of the hole, this tendency is greatly reduced. When the filing is to be done on an internally curved surface of a large radius, as shown in Fig. 55, a

half-round file is used. As in the case of the circular hole, there is a tendency to file unevenly, and a file of as large a curvature as is obtainable should be employed. The file should be moved along the circumference of the curve as well as across the work, which gives it a diagonal motion, and in addition to the advantages of diagonal filing on flat surfaces, prevents the formation of ridges.

83. Filing Into Corners.—When forming a sharp corner, or filing up to a finished surface that stands at right angles to the one on which the filing is done, a safe-edge file is used, thereby preventing any injury to the finished part. When the corner is to be extremely sharp, a half-round file may be employed, or a flat file may be ground off on one side to form a safe edge. Either the half-round or a flat file ground in this way has a sharp edge that will permit a sharp angle to be formed. Some forms of triangular files will also make a sharp corner. The other files used in ordinary work are so cut that the corners are either rough or slightly rounded and will not make a clean, sharp angle. When the corners are to be rounded, a round-edge file will give good results.

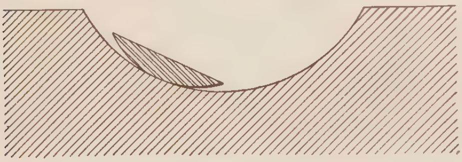


FIG. 55

84. Draw-Filing.—When the filing is done by moving the file sidewise over the work, it is called *draw-filing*. Fig. 51 illustrates how the file is held, the motion being at right angles to its length. Draw-filing is used very generally in finishing turned work, where it is desired to remove the circular tool marks and lay the marks endwise. The file must be held so that the teeth will cut as it moves away from the body and the pressure will be relieved on the return stroke, as in cross-filing.

Very smooth work may be done by draw-filing. The cut is not so deep as in cross-filing, the teeth standing at such an angle to the direction of motion that a light shearing rather than a cutting effect is produced. A second-cut or smooth file is best

suited for draw-filing. On convex surfaces a flat file or the flat side of a half-round file may be used; but in concave work a round file or half-round file will give the best results. When a large amount of metal is to be removed it should be done by cross-filing, as the cut in draw-filing is so light that a very great amount of time would be required to remove it by this method.

85. Finishing Filed Work.—When a better finish is required than can be produced by draw-filing, the surface may be rubbed with fine or worn emery cloth and oil, the cloth being wrapped about a file or a piece of wood, which is used as in draw-filing.

86. Position of Body.—No attempt should be made to keep the body rigidly in one position while filing, especially on heavy work. A free, easy motion of the body, in the direction in which the file is moving, permits a greater force to be exerted without undue strain. In filing right-handed, the workman stands with his left foot toward the work, and as the file is moved forwards, a slight bending of the left knee will tend to throw the body against and upon the file, thus assisting in making the cut. During the return stroke the knee is again straightened as the body returns. A little practice will show the extent to which this motion of the body can be made to assist in the work.

87. Height of Work.—The height of the work largely depends on the class of filing to be done. Ordinarily, the surface to be filed should be about as high as the elbow of the workman. Extremely heavy work should be set somewhat lower, in order that a greater pressure may be put upon it. If the vise or supporting device is too high, a foot-board or low bench may be used to stand upon. The feet of the bench should be set flush with the ends of the foot-board in order to prevent tipping when stepping on the ends.

88. Effect of Oil.—The effect of oil on filing varies greatly with different metals and different classes of work. In finishing broad, smooth surfaces of cast iron, the presence of oil prevents the file from cutting, and causes it to slip over

the surface, thus wearing off the sharp points of the teeth. On cast iron generally, and especially on the class of work mentioned above, oil should never be used. On the other hand, it may be advantageously employed when filing wrought iron and steel, and hard fibrous materials, especially in finishing surfaces, when the file is new and sharp. Oil prevents the file from scratching and cutting too deeply. Sometimes the teeth are filled with chalk, either dry or mixed with oil; this helps to prevent the filings from clogging between the teeth. New files are usually sent from the factory covered with oil, to prevent their rusting. For work in which oil is objectionable this must be removed, which is sometimes done by first rubbing off the surplus oil, then coating the file with chalk and brushing it off carefully.

89. Selection and Care of Files.—The life of a file may be prolonged by exercising care in selecting a suitable one for each piece of work, and in using it properly. A new file should never be used on rough cast iron from which the sand and scale have not been removed, nor on narrow surfaces. Both these conditions tend to break and dull the teeth. A worn file will do excellent service in both these cases. On narrow work, a worn file will give better results than a new one, the teeth on a new file being so sharp that the few teeth in contact will enter so deeply that they are liable to be injured and to scratch the work. A new file should be first used on brass or wide, smooth, cast-iron surfaces.

The files most commonly used in the machine shop are the 12-inch and 14-inch flat and half-round, double-cut bastard, and the 12-inch and 14-inch mill bastard. The other files mentioned are, of course, needed very frequently for finishing, or for special operations, and should be kept in stock.

90. Pinning of Files.—The tendency to pin is one of the most serious troubles to be met in filing. *Pinning* is the clogging of the cuttings in the file teeth, forming hard, sharp pins that scratch the work. It occurs more readily in some materials than in others. As soon as the slightest indication of pinning is observed, great care should be taken to keep the

teeth cleaned. Sometimes this may be done by rapping the file against a wooden block or the work bench, or by rubbing the hand over it. A wire brush, called a *file card*, shown in Fig. 56, is used in most cases. Vigorous brushing in the direction of the teeth usually removes the pins, but in cases where the brush will not remove them, a piece of soft sheet brass, or copper or iron wire flattened out at one end, may be used. The end is pressed crosswise upon the teeth and moved in the direction of the length of the teeth. Little grooves will be cut in the soft metal, forming small teeth that clean the file thoroughly.

91. Care of Files.—In too many cases, tools of all kinds are thrown into a box or cupboard promiscuously, resulting in injury to the files and all other cutting edges, to say nothing of the slovenly appearance of the place and the time wasted in searching for anything that is wanted. A tool box or cupboard should always be kept in order. There should be "a place for everything and everything in its place," when not in use. Files should never be thrown upon one another, or upon other tools or hard substances. They should be laid either on shelves or in a drawer that is provided with small divisions, to prevent their rubbing against each other. They should always be carefully cleaned before they are put away, and kept in good condition so as to be ready for use when they are required.

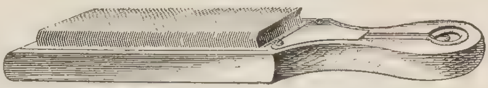


Fig. 56

92. Filing Jigs.—In the making of duplicate parts, filing jigs are generally used, and also in a great variety of operations where it is necessary to produce accurate work by filing, and to do this practically independent of the skill of the workman. Such jigs usually consist of hardened steel blocks fastened to the work, and made in suitable shapes to guide the file so as to remove the stock to the proper form in each case. The file will glide over the hardened jig practically uninjured and cut away the softer metal of the piece of work which projects above it.

93. The form of jig shown in Fig. 57 is used in making rectangular slots in boring bars, etc. It consists of a hardened steel block *a*, having a hole for inserting the work *b*; a slot *c* of the dimensions required to be made in the work; a series of holes *d* at right angles to the slot *c* and circumscribed by a rectangle same as *c*; and a setscrew *e* to hold the jig on the work.

94. In cutting such a slot in a bar, the jig is slipped on to the proper position and clamped by means of the setscrew. The holes are then drilled through the work, those in the jig serving to guide the drill. The setscrew is then loosened and the jig turned 90°, bringing the opening over the holes just drilled. A

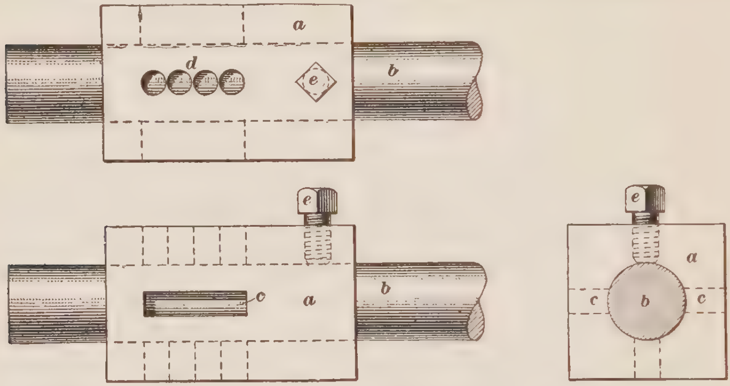


FIG. 57

drift may be used to drive out some of the metal between the holes, after which a file is employed to bring the slot to the form of that in the jig.

A better way is to move the jig a half hole endwise, then, using the drill press, run a **butt mill**—that is, an end mill having end teeth only—through each hole of the jig to remove the metal left between the holes by the drill; the slot may then be finished by filing as described above.

95. Filing Machines.—Filing machines are used to file rough flat work on which heavy cuts may be taken; such as small castings of iron, brass or steel, forgings, stampings, etc. On them much work generally done on shapers, milling machines or disk grinders may be done more quickly.

One form of filing machine is shown in Fig. 58. The work *a* is held in an ordinary vise *b* attached to the table *c* of the machine, and is set square by the use of the straightedge *d*,

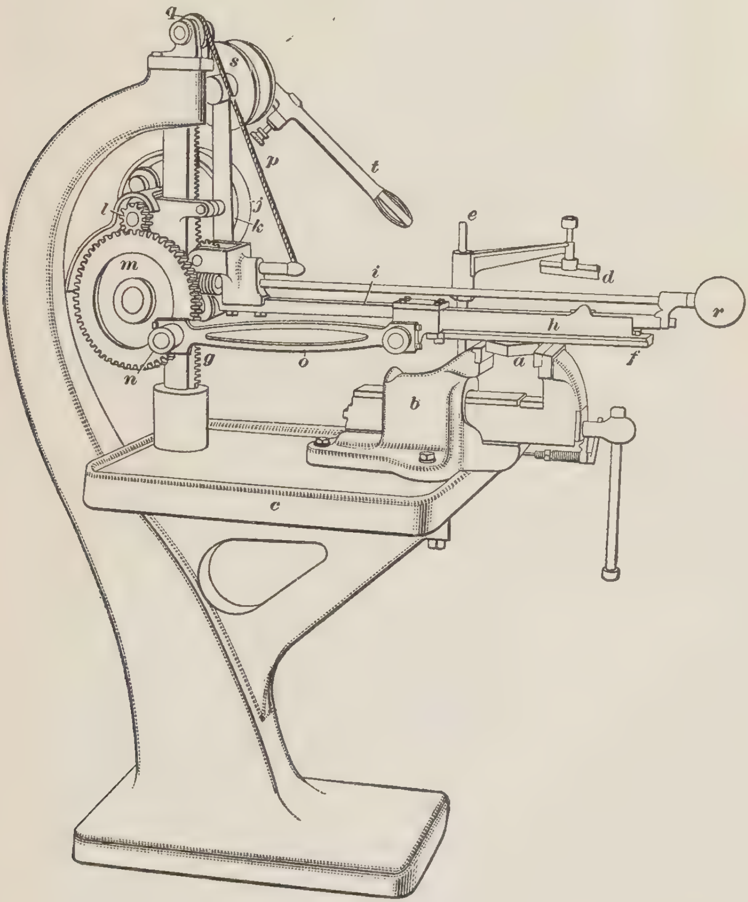


Fig. 58

which is adjustable about the standard *e*. The mechanism carrying the file *f* is so constructed that it may be moved in a horizontal plane about the pillar *g*, and is, of course, moved out of the way before adjusting the work in the vise.

The file has a flat face and is carried on the holder *h*, to which it is attached by means of screws. The holder has a reciprocating motion along the guide *i*. The machine is driven by a belt from overhead, operating on the tight and loose pulleys *j* and *k*. The pinion *l*, which is keyed to the same shaft as the tight pulley, drives the gear *m*. This gear, by means of the crankpin *n* and rod *o*, imparts the desired motion to the file holder *h*.

The weight of the guide bar, file holder, and other parts is counterbalanced by a weight in the base of the machine, which is attached to the cord *p*. This cord passes over the pulley *q* and through the stationary pillar *g*. By turning the wooden ball *r*, the counterbalanced body of the machine may be raised or lowered to set the file level or at an angle with the work. The flanged pulley *s* over which the belt runs serves to keep the belt taut, and, by adjusting the starting lever *t* sidewise, the flanged pulley shifts the belt. When filing, pressure is applied by the hand to the ball *r*.

96. Sharpening Machines for Circular-Cut Files. When files become dull, they are sometimes resharpened. Owing to the fine spacing and shallow depth of the file teeth, the sharpening of single- and double-cut files has met with little success. In circular-cut files, the teeth of which are widely spaced and relatively deep, the resharpening has proved advantageous.

A form of file-sharpening machine adapted to the resharpening of circular-cut files is shown in Fig. 59 (*a*). The base *a* of the machine carries a table *b* which has a crosswise movement controlled by a screw and knob *c*. On the table is a carriage *d* with wheels *e* that roll on the **V**'s *f* of the table. On the carriage the file *g* to be ground is held. It is placed against the stop-plate *h* and is held in position by the jaw plates *i*, which are moved crosswise by turning the knobs *j*.

The grinding wheel *k* is secured to the shaft *l*, to which the pulley *m* is keyed. The pulley is driven by belt from an overhead shaft. The shaft *l* has its bearing in the wheel bracket *n*, which can be moved back and forth on a horizontal slide *o* by means of the screw *p*. This slide is swiveled on the pin *q*, which

is fixed in a vertical slide *r*. The wheel, wheel bracket, and swivel are swung about the swivel pin by the lever *s*, which is operated by hand. The vertical slide *r* is moved by the screw *t*, on the bracket *u*. The bracket is bolted to the base of the machine. A guide finger *v*, view (*b*), bears against the teeth of

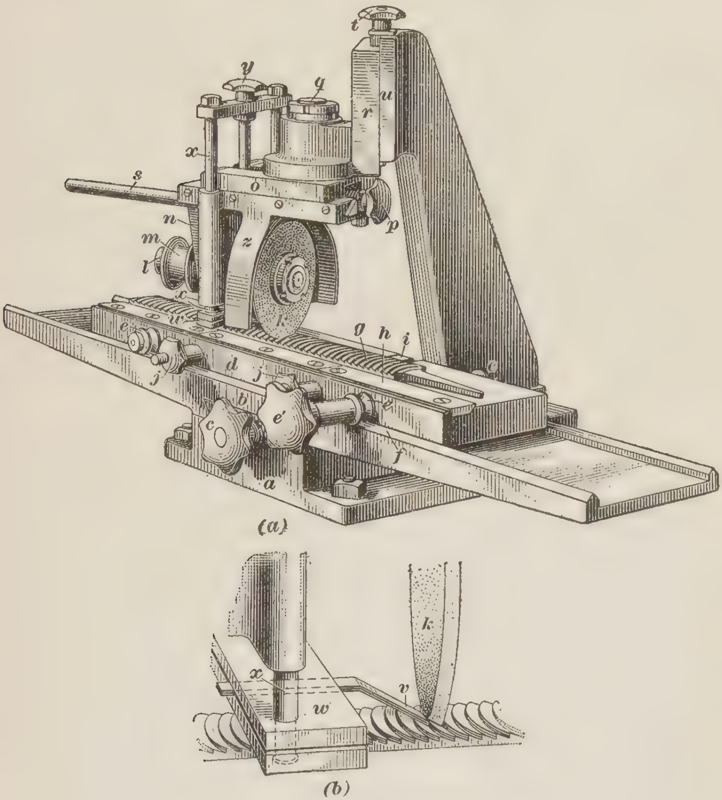


FIG. 59

the file and locates them in position for grinding. It is held in the yoke *w*, which is secured to the rods *x*. These rods slide in the wheel bracket *n*, view (*a*), and have a vertical movement controlled by the screw and knob *y*. The grinding wheel *k* is thin, is well supported by flanges, and is covered by a guard *z* to prevent the pieces from flying if the wheel should break.

97. In operation, the file is secured to the carriage of the machine, the wheel is trued to an angle a little less acute than that of the file tooth, the table is adjusted crosswise until the file is located centrally under the wheel, and the guide finger is set against the tooth of the file farthest to the right. By turning the knob p, Fig. 59 (a), the radius of the arc in which the wheel swivels is adjusted until it corresponds with the radius of the teeth of the file. The wheel is now adjusted vertically, by means of the knob t, to grind the first tooth. When grinding, the right hand is placed on the knob e', and, by applying a slight pressure toward the left, the tooth to be ground is kept against the guide finger. The lever s is then operated by the left hand, and the grinding wheel is passed back and forth over the work. The wheel is now swung free of the file, the guide finger and carriage are set to grind the next tooth, and the operation is repeated. This process is continued until all the teeth are ground.

BENCH, VISE, AND FLOOR WORK
(PART 2)

BENCH AND FLOOR WORK

SCRAPING, BROACHING, AND KEY FITTING

SCRAPING

1. Use of Scrapers.—Scrapers are used in machine construction to fit or correct flat bearing surfaces to each other and to make flat or curved surfaces true. Flat surfaces are first planed, or in some cases milled, as true as possible; but owing to the unequal hardness or texture of the material, the possible springing of the work when clamped on the planer or milling-machine table, and the slight wear of the finishing tool, they are never perfect as they leave the machine. Such errors in planed surfaces as are corrected by scraping are caused in several ways, among which are: wind, from not having the casting or piece firmly bedded on the table; out of square, from using try squares that are not true; from angles that do not match; and from sand holes, spots of scale, and hard spots that the tool jumps or slides over. The errors in planed work should not exceed one or two thicknesses of tissue paper; if greater, the work should be replaned unless the errors are due to hard spots.

2. Forms of Scrapers.—The scrapers used on flat and angular work are the *flat*, the *hook*, the *right-hand hook*, and

the *left-hand hook;* and for curved work, the *half-round* and *half-round end* are much used. For removing burrs and scraping corners and countersunk surfaces, the *three-cornered scraper* is generally used. The flat scraper is the one most employed, as it is the most easily made, sharpened, and used, and in expert hands it will remove an astonishing amount of surface in a short time with little effort.

Scrapers are often made of old files; but they do not work as well as those forged from special scraper steel, because files are made of a grade of steel, called *file steel*, that can be properly hardened only by special processes. Scrapers that are not shaped like files are never made from them. The half-round and three-cornered scrapers may be made from any good smooth or dead-smooth files that have become too dull to use,

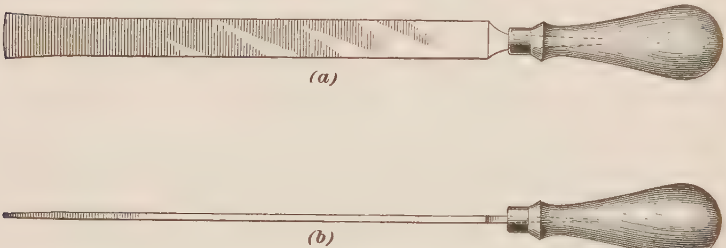


FIG. 1

by simply grinding off the teeth, thus avoiding the necessity of rehardening. When scrapers are made in this way, care must be taken not to draw the temper of the steel when grinding.

3. The **flat scraper,** Fig. 1 (*a*) and (*b*), should be made of special scraper steel stock about $\frac{3}{16}$ inch thick by 1 inch wide, with a tang, similar to that on a file, which is driven into a wooden handle. The cutting edge should be drawn to about $\frac{1}{16}$ inch thick by $1\frac{1}{4}$ to $1\frac{5}{8}$ inches wide, and hardened to the greatest possible degree.

4. The sides *a* and *b* of the scraper are ground a little high in the center as shown exaggerated in Fig. 2 (*a*), which is an end view of Fig. 1 (*b*). The end is slightly rounded, as shown in Fig. 1 (*a*). When grinding the end a small grinding wheel

and the tool rest are used. The height of the tool rest is set so that when one of the broad sides of the scraper is laid on it, the plane midway between the sides will pass through the center line of the wheel. Keeping the broad side of the scraper flat on the tool rest, the end is ground rounding, as shown in Fig. 1 (*a*), and at the same time hollowed, as shown at *g*, Fig. 2 (*b*), which is an enlargement of the end of Fig. 1 (*b*). The surfaces *a* and *b*, Fig. 2 (*b*), are next rubbed on an oilstone, after which the tool is held in a vertical position so that both of the points *c* and *d* will rest on the

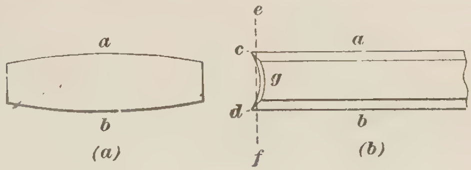


FIG. 2

FIG. 3

stone, in which position it is rubbed back and forth, grinding it into the shape shown by the dotted line *e f*. It is now ready for use and has an equally good cutting edge on each side.

5. The **three-cornered scraper** may be made of a worn-out file. All the teeth are ground off and the end is ground to

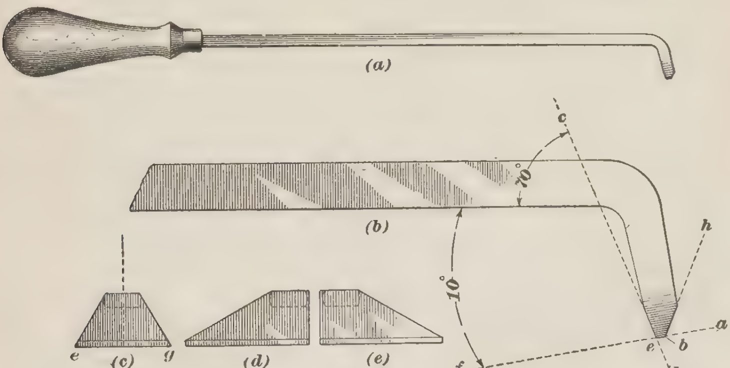


FIG. 4

an angle of about 60°. It is best to do the work on a wet grinding wheel, for, if a dry wheel is used, the tool would be easily

overheated and spoiled. The appearance of the finished three-cornered scraper is shown in Fig. 3. In some cases the edges from *a* to *b* are slightly curved.

6. The **bent,** or **hook, scraper** is made in the form shown in Fig. 4 (*a*). An enlarged view of a portion of the tool is shown in (*b*), and an end view is illustrated in (*c*). This scraper should be ground to the angles denoted by the lines *a f* and *c d* in view (*b*). The cutting is done with the edge *e g*, in (*c*), and the metal is removed by pulling the tool toward the operator. The face *b h* in (*b*) is ground to any convenient angle, reducing the thickness of the clearance face *e b* to from $\frac{1}{32}$ to $\frac{1}{16}$ inch. As with all scrapers, the final sharpening of the cutting edge is done by rubbing it on an oilstone. This scraper is used for frosting or flowering; that is, the finishing of the surface in imitation of frost or designs. This tool is sometimes made with the end bent at right angles to the body of the scraper instead of as shown.

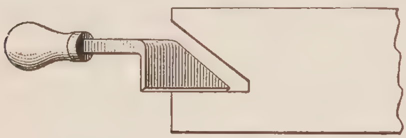


FIG. 5

7. Right- and left-hand hook scrapers are also shown in Fig. 4. The top view of these scrapers is shown in (*b*), the end view of the left-hand scraper in (*d*), and the end view of the right-hand scraper in (*e*). Scrapers of this form are employed to scrape surfaces that cannot be conveniently reached by the regular hook scrapers. They are used for both scraping and frosting, like the regular hook scrapers, by pulling the cutting edge toward the operator. In Fig. 5, a left-hand hook scraper is shown in position to scrape the lower side of a gib way. These tools are made with their ends bent at right angles to the body of the scraper more frequently than are the regular hook scrapers.

8. Scrapers for curved work are shown in Fig. 6. Fig. 6 (*a*) illustrates a form used for scraping bearings and similar work. It is made of scraper steel and fitted to a file handle. The scraping is done by pulling the scraper toward the operator.

The scraper shown in Fig. 6 (*b*) is made of a half-round file by grinding off the teeth, heating and bending to the desired shape, and hardening the file. If heating to a bright red and quenching in water does not harden it, case hardening is necessary. The scraping edges *a* of the tool are finished by oilstoning. This tool is largely used for scraping bearings. When made straight, as is sometimes the case, it is not heated, and care is taken not to draw the temper of the steel when the file teeth are ground off.

In Fig. 6 (*c*) is shown a form of *half-round end scraper* which is much used for scraping half-round channels such as oil grooves. It may be made from a worn-out, half-round file, although better results will be obtained when it is made of regular scraper steel. The scraping edge is that marked *b* in the figure.

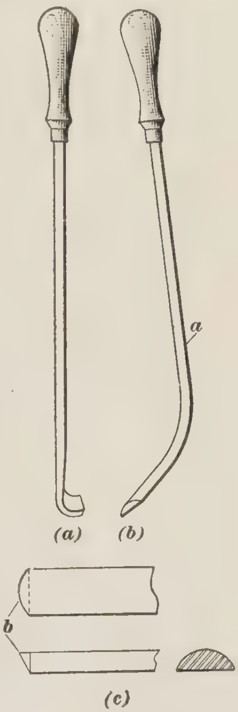


FIG. 6

9. Holding Scraper.—The manner of holding the flat scraper is shown in Fig. 7. The handle is held in the right hand with the thumb extended along the top, in order to keep the hand and arm in line, the same as in filing, thus preventing cramping the hand and tiring the arm. The left hand grasps the scraper as near the cutting edge as is convenient, and only enough pressure is applied to remove the required amount of metal. The cutting is done by pushing the scraper away from the operator, except where it is used for frosting, flowering, or finishing, when a long handle may be substituted and rested on the shoulder, while both hands are used to pull the tool toward the operator. The hook scrapers are held in much the same way as the flat scrapers, but are pulled toward the workman.

10. The flat scraper is usually held at an angle of about 30° to the surface of the work; but this angle may vary with

the material scraped and the condition of the cutting edges. No definite angle can be given for other types of scrapers; it must be determined by trial with each scraper and each class of work.

11. Preparation of Surface.—When a newly planed surface is to be finished by scraping, the piece is first placed on any support that will bring it up to a convenient height for the workman, and any dust or dirt that may be on the surface is brushed off. A smooth or dead-smooth file is run over the surface, to remove any burrs or fuzz; and any marks that would

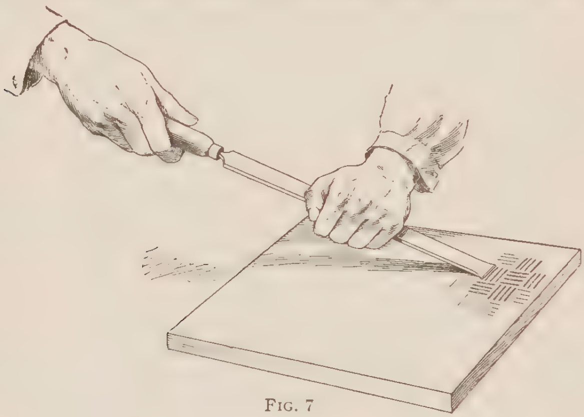


FIG. 7

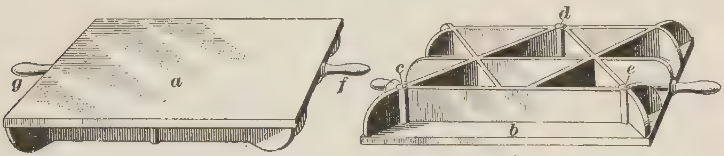
indicate that a sand hole or hard spot had left a high spot or spots, are removed by filing.

12. Marking Mixtures.—To assist the workman to locate the high spots of the surface being scraped, marking mixtures are used. These mixtures may consist of red lead, Venetian red, or any red or black material that is not gritty. Venetian red is better than red lead, as it is much finer in texture. The marking is rubbed with the hand into a thin coating as evenly as possible over the surface plate on which the work is tried. The marking mixture should be kept in a covered tin box, so that it may be kept clean and free from grit.

13. Surface Plates.—In machine construction, the surface plate is used for testing flat surfaces. It is generally made

of a hard, close-grained iron casting having a flat top *a*, Fig. 8 (*a*), supported by a ribbed back *b*, Fig. 8 (*b*). Three legs *c*, *d*, and *e*, are provided, so that the plate will stand evenly on any surface. On the ends are handles *f* and *g*, (*a*), by which the plate may be lifted. The tops of these plates are first planed as smooth as possible, then filed and scraped perfectly flat.

14. When in use, the surface plate is coated lightly with marking material, after which the plate is rubbed over the surface that is to be trued. The marking material is left on the high places, thus showing the parts that are to be removed with the scraper. This operation is repeated until the surface shows a good bearing at all points. Small work is rubbed on the plate. Every part of the surface plate should be used as evenly as possible, for if the rubbing is all done in one place, the plate will soon be spoiled. Surface plates are made of different



(*a*) (*b*)

FIG. 8

sizes to suit the work. Special plates are often made for work, in places where it is impossible to use a plate having a ribbed back.

15. Applying Surface Plate.—The surface plate is prepared by thoroughly cleaning and coating it with marking material. It is placed face down on the work and rubbed back and forth a few times over the entire surface. No pressure is necessary, the weight of the plate being sufficient. When the plate is removed, irregular patches of the marking material will be found on the work. These places indicate high spots in the surface, and they are removed with a few strokes of the scraper. The workman now wipes his hand clean of grit and rubs it over the entire face of the surface plate, to smooth the marking, and then rubs the plate over the work again. More bearing spots will be shown this time, which are removed with

the scraper. The work proceeds in this manner until the entire surface of the work is covered with bearing marks, when it may be called true.

16. The marking material, in addition to showing the high spots on the work, acts as a lubricant and prevents undue wear on the plate and the cutting or scoring of both the work and plate. The more true the surface operated on becomes, the thinner should be the coating of marking on the plate. For some purposes the marking does not afford sufficient lubrication, and additional oil would prove detrimental to the work. In such cases a plentiful supply of turpentine should be used on the surfaces while they are being rubbed together. In addition to lubricating the surface, turpentine also facilitates the work of scraping.

HAND BROACHING

17. Broaching, or **drifting,** is the process of forming holes by forcing a cutter of the exact form required through holes previously drilled. In all broaching operations, the greatest amount of stock possible must be removed by drilling, and if much remains the broaching tools should be so designed that each tool will take out an equal amount of material.

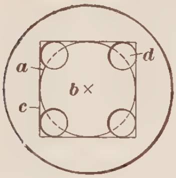


FIG. 9

For cutting most metals, broaches require an abundant supply of lard oil. When broaching cast iron, oil is not so essential for the cutting operation; but the back and sides of the broach should be well lubricated.

18. Simple Square Broach.—The form of broach depends largely on the nature and quantity of the work to be done. If the number of pieces to be broached is small, the broach must be as inexpensive as possible. In this case, most of the work is done by the drills, or other means are used to rough out the hole, and the broach depended on only for finishing.

Making a socket to fit a $\frac{1}{2}$-inch square in a tap socket or a chuck-screw wrench is a simple example of broaching. The square may be laid out on the end of the round stock, as in

Fig. 9. A $\frac{1}{2}$-inch circle *a* is first drawn from the center mark *b*, and the square *c* is laid off. Four $\frac{1}{8}$-inch holes *d* are now

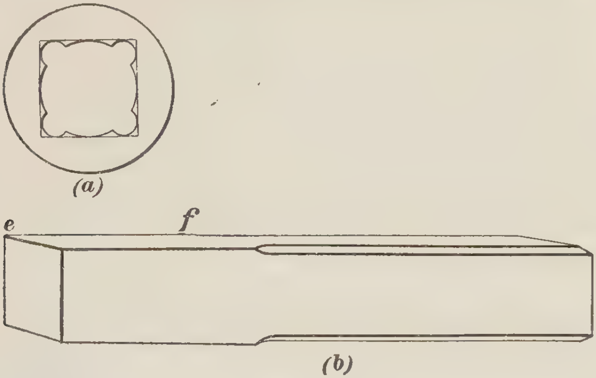


FIG. 10

drilled $\frac{1}{8}$ inch deeper than the square hole is to be and just touching the lines of the square. The $\frac{1}{2}$-inch hole is next drilled, which leaves the hole as shown in Fig. 10 (*a*). A square broach may now be driven to the bottom of the hole. Fig. 10 (*b*) shows this form of broach; it tapers a little from the cutting edge *e* to *f*.

19. Another Form of Square Broach.—Fig. 11 shows a broach and a broached piece. The broach in this case has rounded corners, which illustrates a practice that should be followed wherever practicable, as teeth of this form are much less liable to break than those of square-cornered broaches. The notches *a* allow the broach to be started without taking the whole cut, and when it has entered far enough to have

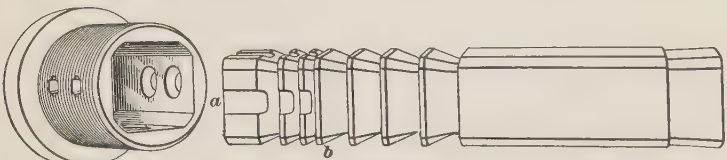


FIG. 11

sufficient support to steady it, the whole teeth *b* commence cutting and finish the work.

20. Use of Several Broaches in a Set.—When a considerable amount of any given class of work is to be done, it is best to use several broaches following one another, each removing a portion of the stock. In the case illustrated in Figs. 9 and 10, the greater part of the metal at the corners is removed by drilling small holes, and in some cases additional metal is chipped out. Where much of this work is to be done, all the metal in the corners may be removed by passing a series of broaches through the work. In Fig. 12, the forms of four broaches for squaring a $\frac{1}{2}$-inch round hole that extends through the piece are shown at *e*, *f*, *g*, and *h*. All the broaches should

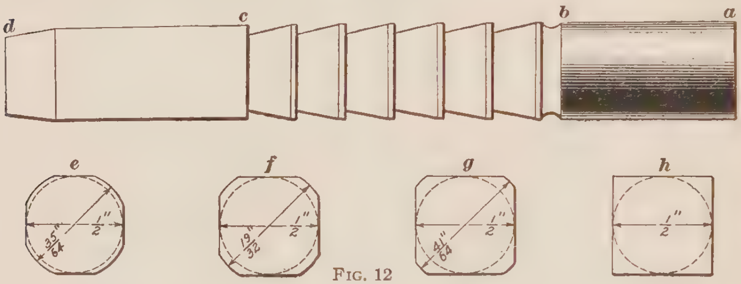


FIG. 12

be provided with several cutting edges, as shown between *b* and *c*, and a guide pin, as shown at *a b*, Fig. 11.

21. Broaching Keyways.—Keyways can be cut to best advantage by the use of special machines for the purpose; but may be finished by hand broaching more quickly and accurately than by chipping. Sometimes, quite large and long keyways are formed in this way, the broaches being driven by means of sledges.

The necessary tools for broaching a tapered keyway are shown in Fig. 13. A plug (*a*) is turned to the diameter *c d* so that it fits the bore of the hub in which the keyway is to be cut. It is made of sufficient length to pass entirely through the hub, and is provided with a collar *c*, which rests against the hub when in use. A slot or keyway having the same taper as that required in the hub is cut in the plug, as indicated by the dotted line *a b*.

22. The cutting is done by the tool shown in Fig. 13 (*c*). The cutting edge is at *j*, and the thickness *g j* must be equal to the depth of the narrow end of the slot *b d*, view (*a*). In order to make the broach cut, liners are placed in the groove behind the broach; one of these liners is shown in (*b*). They are made of sheet metal, and, if the keyway is a large one, after several thin liners are in place they may be removed and

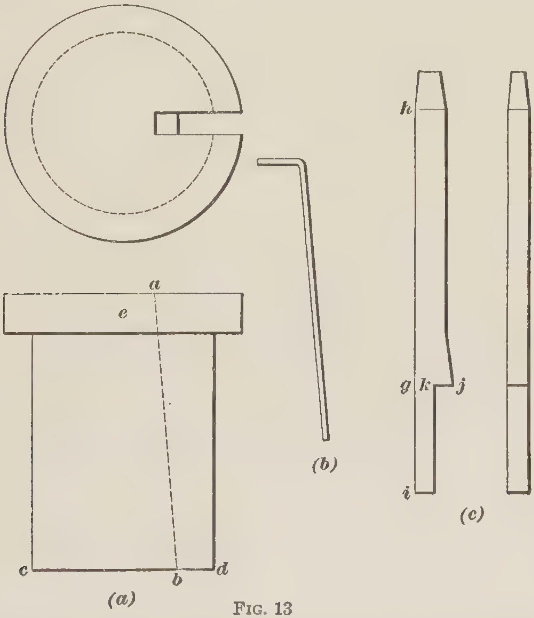


Fig. 13

replaced by one thick one, after which the thin liners may be replaced one by one, as the successive cuts are taken.

The broach is provided with a guide *g i*, view (*c*), which enters the hole first, and the portion *g h* must be at least equal in length to the slot *a b*, view (*a*), so that the broach can be driven clear through. The face *j k*, view (*c*), of the broach should be perpendicular to the face to be cut. The broach, if very large, may be made of machine steel and provided with an inserted blade or cutter at *j*. The cutting edge of a broach should be hardened to a brown or dark straw color.

FITTING KEYS

23. Rectangular Keys.—Keys of a square or rectangular cross-section are generally planed or milled a little larger than the size of the key seats they are to fill, and are then filed to fit. If the key is to fit the top and bottom, it should be filed true to a surface plate and made of such width as to fill sidewise the keyways in both the shaft and wheel. The corners, as well as the ends, should be slightly rounded. The shaft is now put into the bore, with the keyways in line. Red or black marking should be put on the surfaces of the keyway, and the key driven in lightly and taken out and filed where it shows bearing marks. The key should not be driven too tightly at first, as it is easily sprung to conform to the inequalities of the hole, and will show too great a bearing. Neither should it be driven in dry, as it will surely cut. The marking applied to the seat is sufficient at first, and later the marking material may be put on the key, where it serves the double purpose of marker and lubricant. By repeated trials, the key is brought to fit the seat perfectly, and then may be driven home without danger of throwing the work out of true.

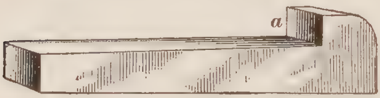


FIG. 14

24. A well-fitted hub and shaft may be forced considerably out of true by driving a key that is tight only on one end; and poorly fitted wheels and shafts may be made to run reasonably true by carefully fitting the keys and trying the work on lathe centers as it progresses. If means are not at hand for machining keys, as is often the case on repair work, a wooden pattern is first made and the key forged a little large, after which the scale may be ground off on an emery wheel or grindstone and the key filed to fit.

25. Provision for Withdrawing Keys.—When keys can be driven out by putting a set in the opposite end of the keyway, they are not provided with heads; but if the keyway is so located that only one end is accessible, that end must be

provided with a head, as shown at *a*, Fig. 14, for the purpose of withdrawing the keys. A pinch bar, or wedge, is used between the head *a* and the hub, to back this key out.

FIG. 15

26. For convenience in fitting, large keys are sometimes made with an extension head 3 or 4 feet long, as shown in Fig. 15. While backing out such a key, it should be supported by holding a sledge under the head at the point *a*, while blows are being struck against the face *b*.

27. Taper of Keys.—When keys are made with a taper, the taper is generally given on the drawing; but in some shops the workman is left to determine this for himself; in common practice, $\frac{1}{16}$ inch to $\frac{1}{8}$ inch per foot is found sufficient.

28. Round Keys.—Sometimes a cylindrical or tapered pin is used as a key. In this case a hole is drilled one-half in the shaft and one-half in the hub; and if the key is to be tapered, the hole is reamed to the proper taper. A tapered key is then turned to fit the hole, and fitted by filing in the lathe, after which it is driven home. For very small work where there is not much strain on the parts, this style of key may do very well. It is used very generally to fasten the hand wheels of globe valves to the stems. For large work, and especially where there is not a good fit between the hub and the shaft, such a key should never be used, as it has a tendency to burst the hub.

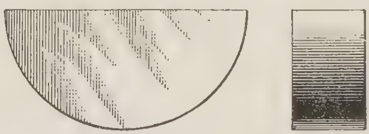


FIG. 16

29. Woodruff Keys. The keys of the form shown in Fig. 16 are known as Woodruff keys, and are made by cutting a disk from a piece of cold-rolled stock. The key seat in the shaft is made by sinking a milling cutter of a diameter corresponding to the curve on the key into the shaft to such a depth that the proper amount of the key will be left

out of the shaft. The key is driven into the shaft, and the wheel, which has previously had a keyway cut in it whose depth is one-half its width, is driven lightly on the shaft. If the work has been correctly done, the key has only to be filed slightly to let the wheel into its place. This key bears sidewise, and should just fill the top and bottom. It is a short key, and when a greater length is required two or more are put in line.

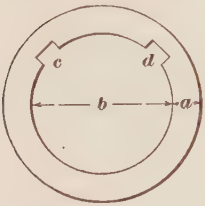


FIG. 17

30. Gauges for Laying Out Keyways. Different types of gauges have been adopted for laying out keyways on shafts and in bores having more than one keyway. For general work, the form shown in Fig. 17 will be found very useful. This gauge consists of a ring of cast iron *a* that is bored to the correct diameter *b*, and that has the necessary keyways laid out in it, as shown at *c* and *d*. This ring may be slipped over the shaft, and the keyways marked from it; it may then be removed and placed on a hub of the crank or wheel, and the keyways on it also marked out, thus insuring the accurate location of these keyways. After locating the keyways with the gauge, they are readily laid out on the shaft or in the bore, using a key-seat rule.

DRILLING, REAMING, AND THREAD CUTTING

DRILLING

31. Portable Drills.—The large amount of hand drilling required on medium and large work has created a demand for portable drills. Their light weight and compactness have made some of them available for much work that was formerly done by hand, and much time and hard labor may be saved by their use. Most of these machines are so light that they can be carried about and operated by one man. For erecting work, where electricity and compressed air are not available, the hand-power portable drills must be used. The several classes of

portable drills are the *pneumatic*, *electric*, *flexible-shaft*, *ratchet*, *crank-driven*, *Scotch*, and *breast drills*.

32. Portable **pneumatic drills** are made in a large number of different forms. Some are driven by means of oscillating cylinders and others by vanes that act through gearing to give the proper reduction of speed. Fig. 18 shows one of the oscillating-cylinder type set up for drilling. The cylinders and gearing are enclosed in a housing *a*. The air, which for this class of work is generally compressed to from 80 to 100 pounds per square inch, is brought from the air compressor or storage

Fig. 18

reservoir to the drill through a rubber hose *b*, the hose usually being protected by wire wound spirally about it. The drill is fed by a screw *c* and is operated as indicated in the illustration. The air is turned on or off and the flow regulated by the throttle valve *d*, controlled by the hand of the operator. This type of machine will drill and ream holes up to 3 inches in diameter, and may be used for various other operations, such as tapping, grinding steam joints, etc.

33. Electric drills have the same general features as the pneumatic drilling machines, the difference being that an

electric motor is substituted for the air motor. An electric drill is shown in Fig. 19. The motor by which the drill *a* is driven is inside the casing *b*, the wires *c* that supply current to the motor being led through one of the handles *d*. The drill is set and held and the feed is obtained in the same way as the drill shown in Fig. 18. If desired, the feed-screw *e* may be removed and the curved plate *f* may be attached instead, to enable the drill to be used as a breast drill.

34. A portable **flexible-shaft drill** is shown in Fig. 20. The power is transmitted to the flexible shaft *a* through a rope drive, the rope running from the pulley *b* on the driving end of the shaft, over a pair of idlers *c* hung from the ceiling, to a pair of idlers *d* attached to the floor, as shown, and thence to the pulley *e* on the countershaft. By either lengthening or shortening the rope attaching the idlers *d* to the floor, the pulley *b* may be moved to any location within the reach of the driving rope. A variable speed is obtained by means of the stepped pulley *e*. The flexible shaft is made by winding successive layers of wire in opposite directions about a center wire, as shown in Fig. 21, the outside being covered with leather.

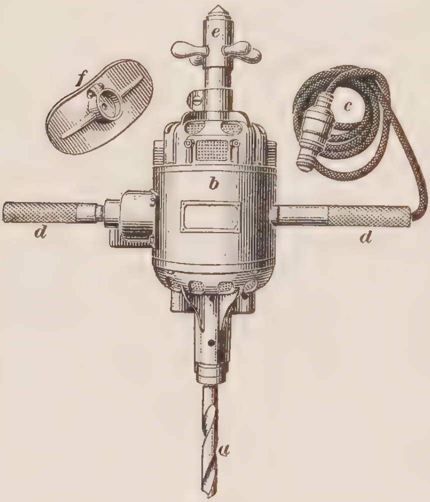


FIG. 19

35. The flexible-shaft drill illustrated in Fig. 20 is shown to a larger scale in Fig. 22. It consists of a pair of bevel gears *a* and *b* mounted in a frame *c*, a spindle *d*, a feed-screw *e*, and a hand wheel *f*. The bevel pinion *a*, which is covered by a guard, is attached to the flexible shaft, and the bevel wheel *b* is splined on the spindle *d*. The drill is held in the spindle in the usual

way, and may be set so as to drill holes at any angle. When no power shaft is available, the flexible shaft may receive its power

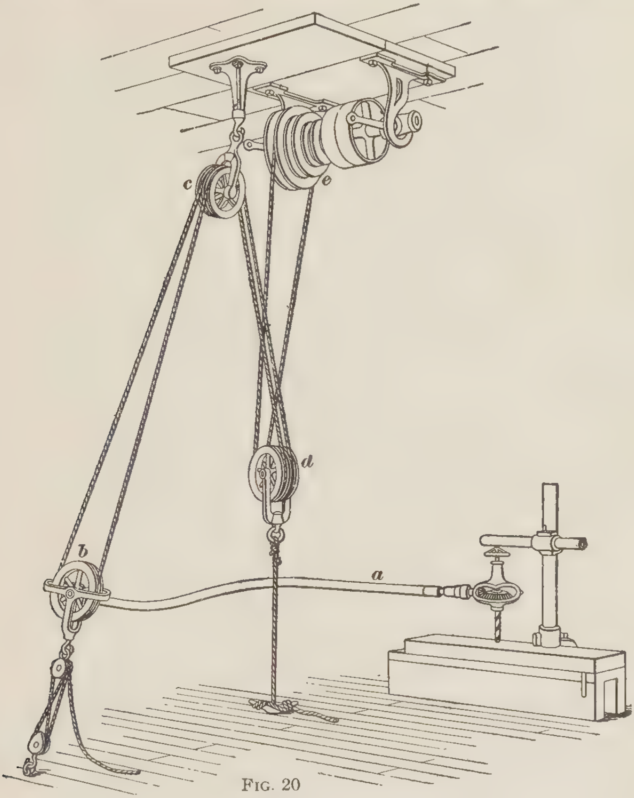


Fig. 20

from any convenient portable source, as, for example, a small electric motor mounted on a truck. The shaft is connected to the motor by a universal joint, so that the arrangement may be as flexible as possible.

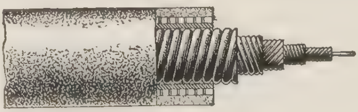


Fig. 21

36. The slowest method of drilling is by means of the **ratchet drill,** but there are occasions when no other kind of drill can be used. Ratchets are generally made single acting; that is, the drill only cuts during the forward stroke of the

handle; but some of the improved ratchets are made to give a forward rotary motion to the drill or cutter during both strokes. Ratchets are made to use both *square-* and *taper-shank* drills. The taper-shank twist drill is the better tool, but odd sizes are often needed by men out on repair work, where it is impossible to get the proper size of twist drill, and a square-shank flat drill can be made by any blacksmith or by the man himself; or a

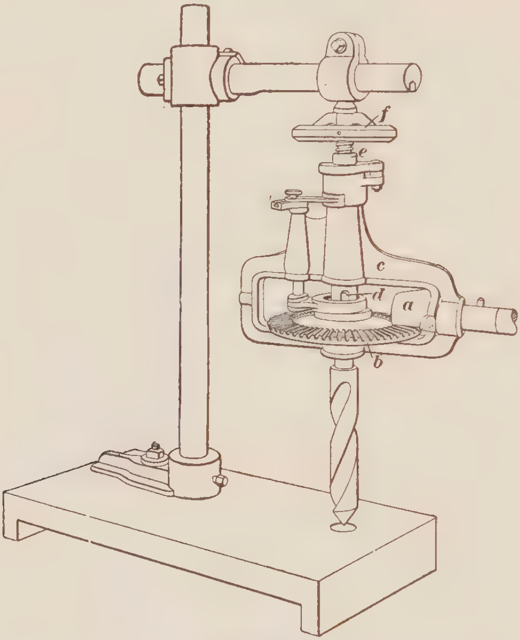


FIG. 22

flat drill already on hand may be made into the required size in a few minutes, either by grinding or dressing.

37. The hole to be drilled with the ratchet is laid out and center-punched in the usual way. Some sort of brace, or, as it is commonly called in the shop, an *old man*, or a *drilling crow*, must be provided that will support the ratchet and drill in the correct position and at the same time allow the drill to be forced into the work by the feed-screw.

The brace, drilling crow, or old man, is made in a great variety of ways, from a piece of flat iron or steel bent to the proper form to the well-designed adjustable one shown in Fig. 23. This brace consists of a base *a*, an upright *b*, and an adjustable arm *c* that is held by the binding screw *d*.

The base is made fast to the work *e* by means of a bolt *f* or clamp *j*, as shown. The arm *c*, which has a number of center holes in its lower face, is set to such a height that the ratchet *i* and drill *g* will go under it. The drill is either set square with

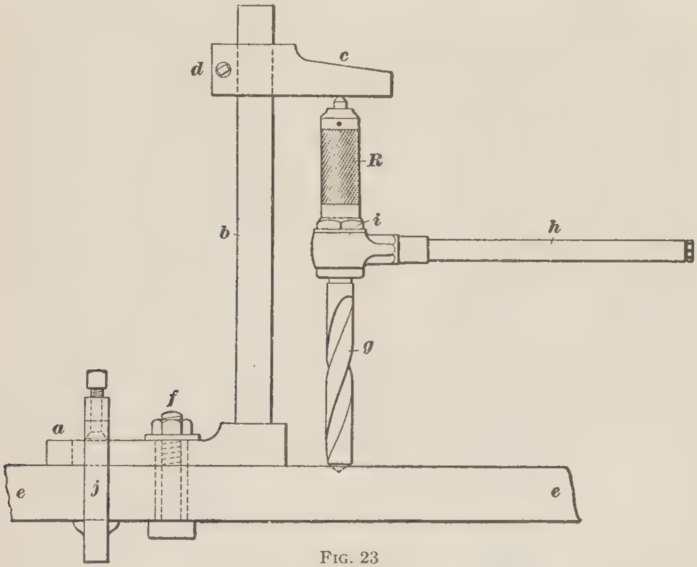


FIG. 23

the work, or so that the ratchet end will lean slightly away from the upright, as the pressure upwards on the arm *c* will spring the upright *b* back and so draw the drill about perpendicular. The drill is rotated by means of the handle *h* and is fed into the work by means of the sleeve *R*.

38. The **crank-driven portable drill** is a better tool than the ratchet, where there is room to use it. This form of drilling machine is clamped to the work, or bench *a*, Fig. 24, and is operated by a crank *b* that gives a continuous motion to the drill *c*. The feed is operated by turning the hand wheel *d*

with one hand, and the crank is turned by the other. The sleeve *e*, carrying the bracket *f*, may be adjusted to varying heights and positions on the upright *g*, being clamped in position by the screw *h*. The bracket *f* may be set to drill vertically or at any angle by adjusting the part *i* on its bearing, and clamping it in position by the handle *j*.

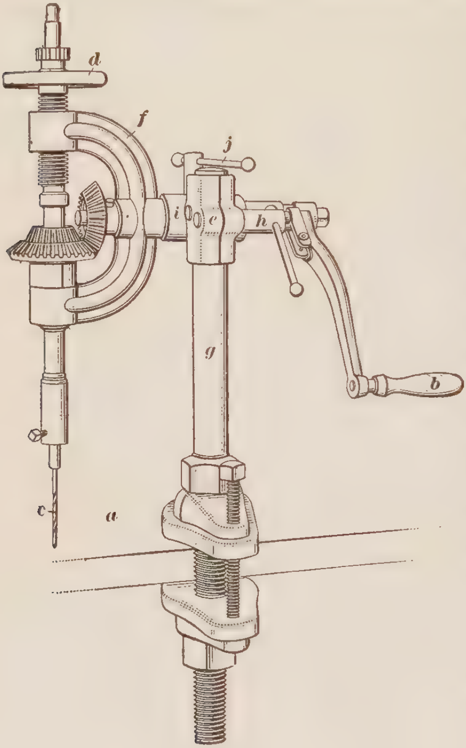


FIG. 24

39. The **Scotch drill** is a drilling device formed very much like an ordinary carpenter's brace. It is usually made by bending a piece of steel or iron so that it will form the necessary crank, fitting one end of it with a suitable socket for the drill, which may be either square- or taper-shanked. The other end is provided with a pointed center that may be fed out by means of a screw, thus giving the feed to the drill. The crank is rotated like an ordinary carpenter's brace, the drill being held in place by a knee or other suitable clamping device. Sometimes the Scotch drill is made with a double crank so that both hands may be used at the same time; but usually only one hand is employed, as the other is required to operate the feed-nut.

40. The **breast drill** is so named because it is provided with a suitable guard that may be placed against the breast while drilling, the feed being obtained by a pressure brought

to bear on the drill by the body. The drill is usually operated through bevel gears by a crank on the side of the machine. This style of drill is very largely used for drilling small holes for attaching name plates, and for similar light work.

REAMING

41. Object of Hand Reaming.—The continued use of machine reamers dulls their cutting edges and at the same time slightly reduces their diameters. For some work, a hole $\frac{3}{1000}$ inch under size, such as would be produced by a worn reamer, would not be objectionable; but, in addition to being small, the hole will be comparatively rough. These defects may be overcome by hand-reaming the hole.

42. Ordinary Hand Reamer.—The hand reamer shown in Fig. 25 illustrates one form of this class of tools. The body *a* is finished to the correct standard size, and the shank is made of such size that it will act as a guide when the hole to be reamed

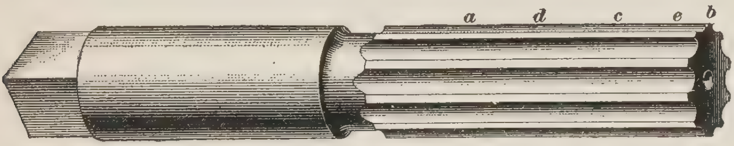


FIG. 25

is longer than the fluted part. The diameter of the part *b c*, equal in length to one diameter of the reamer, is made $\frac{3}{1000}$ inch smaller than the nominal diameter. From *c* to *d*, about one diameter, the reamer is tapered up to the full size, and from *d* up it is parallel. The hand reamer is used, as its name implies, only by hand. The end *e* is entered into the hole left small by the under-sized machine reamer and acts as a guide, and the taper from *c* to *d* removes the stock, while the parallel part *a* maintains the size. The small amount removed insures the durability of the tool and the smoothness of the hole. For cast iron and brass, the reamer should be entered and twisted quickly through the hole. In the case of cast iron, the use of oil is usually thought to give a smoother hole than can otherwise be

obtained, although in many shops it is customary to ream dry. For wrought iron and steel, the reamer should be well lubricated with lard oil.

43. Stepped Reamer.—The reaming of taper holes, particularly large ones, in tough and hard metals, is greatly facilitated by using the stepped reamer illustrated in Fig. 26. The small end *a* of this reamer is made the size of the small end of the hole. A hole of a size corresponding to *a* is drilled into or through the work as required. The stepped reamer is then started in and run to the necessary depth. This reamer cuts only on the end of each step, as at *b*, *c*, etc., the diameter of the reamer being slightly less at the top of each step than at the lower end; for instance, the diameter is smaller at *e* than at *d*, in order that the tool may not bind in the hole. Clearance is also given the cutting edge from *f* to *g*. This reamer is cut

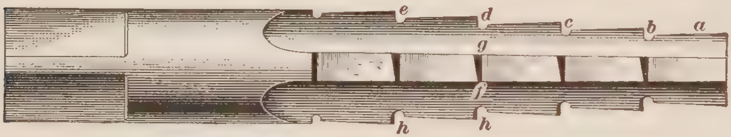


Fig. 26

with four flutes, and therefore has four sets of cutting edges. The half-round notches *h* are cut to make a stopping place for the wheel while grinding. The use of this reamer does away with the necessity of using a number of different-sized drills to prepare the hole for reaming. After the stepped reamer has removed the stock, a notched taper reamer is run in to remove the steps, and finally the finishing reamer smooths the hole.

44. Taper Reaming.—Taper holes are frequently hand-reamed, to make them of the correct size and smoothness. This is done after the stock is removed by the roughing and finishing reamers. The taper hand reamer, when not in use, should be kept in a box or tied up in a heavy paper covering, as any nick or dent on its cutting edges will seriously mar the hole. The reamer must also be used with great care. It should be carefully placed in the hole, well oiled if in wrought iron or steel, and turned with enough pressure to insure its cutting

from the very first; turning a taper hand reamer in a hole when it does not cut will soon ruin it.

45. Advantage of Vertical Reaming.—All reaming, whether hand or machine, is better if done in a vertical position, because the weight of the reamer, if working horizontally, tends to ream downwards, and so either carries the reamer out of line or tends to take more out of the bottom side of the hole. Also, any chips or cuttings will fall out of the vertical hole,

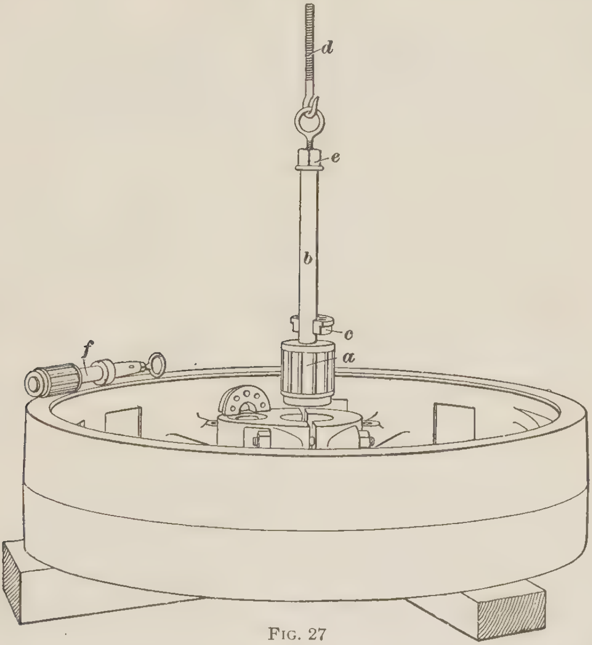


FIG. 27

but in the horizontal hole they remain between the teeth of the reamer and often scratch or score the work.

46. An example of vertical reaming is illustrated in Fig. 27. The pulley shown is first put on the boring mill and turned to $\frac{1}{16}$ inch over the finished size; the hole is bored about $\frac{1}{32}$ inch small and then hand-reamed to size, after which the wheel is put on a mandrel and the face turned true and to size. The reaming is done in the following manner: The wheel is placed

on blocks, as shown, and the reamer's shank *b* is passed up through the bore and hooked to the threaded rod *d*. A split bush *c* is placed around the shank *b* and pushed down into the bore to act as a guide. A double-end wrench is placed on the square of the shank at *e*, and two men walk around the wheel to turn the reamer. The threaded rod *d* passes through a nut, not shown in the cut, and this feeds the reamer *a* upwards through the hole. The reamer *a* is shown just as it leaves the finished hole. Another finishing reamer is shown at *f*.

47. Reaming Holes in Line.—Holes may be reamed in line in the following manner: The holes in two or more castings that are to be bolted together are first laid out as close as possible to their correct location; all those in one piece are drilled and reamed to size, and the corresponding holes in the next piece are drilled about $\frac{1}{8}$ inch smaller; then the two castings are clamped together in their correct position, and a rose reamer, or a reamer which cuts only on its end, the same size as the finished hole, is put through the reamed part of the hole and ratcheted through the smaller hole, thus bringing them perfectly in line. This work must often be done in very contracted or limited spaces.

THREAD CUTTING

48. Methods of Tapping.—Holes are threaded in three ways: first, by cutting in the lathe; second, by using a special tapping fixture in the drilling machine; and third, by hand. The first two methods provide their own means of keeping the tap square with the work; but in hand tapping much depends on the skill of the workman.

49. Hand Tapping.—Two kinds of hand taps are in common use. The first kind, Fig. 28 (*a*), is made with a straight end *b c*, the diameter of which is equal to that at the bottom of the thread. This end fits the hole made by the tap drill, so that by the exercise of a little care on the part of the user a squarely tapped hole is the result.

The other style, Fig. 28 (*b*), is tapered from *d* to *e*; consequently, it will not stand square with the hole. To tap a

hole square with the device shown in (*b*), the tap should be well oiled, placed in the hole, and turned two or three times with a double-ended wrench, which is then removed and a square applied to the tap in the manner shown at *a*, Fig. 29.

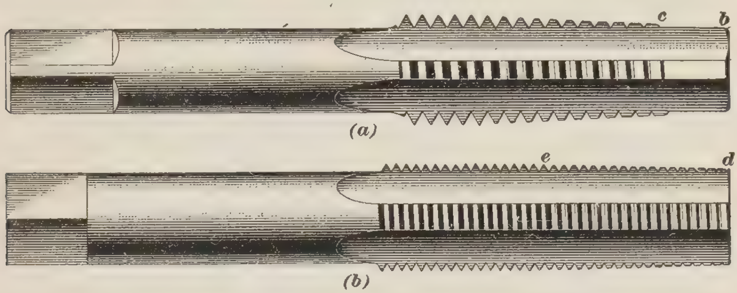


Fig. 28

Try the square at the next flute, and if the tap shows out of square apply pressure enough sidewise on it with the wrench while turning to bring it square with the surface. Repeat these trials until the tap is found to be square. If a square is not at hand, a wide 6-inch steel rule *b* may be used instead. The tap shown in Fig. 28 (*a*) will go in reasonably straight; but, for accurate work, it is better to use the same precautions as with the other style.

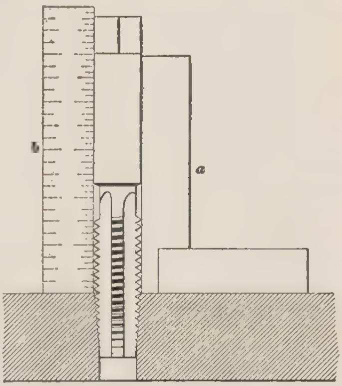


Fig. 29

50. Tapping Jig.—A tapping jig is sometimes used to guide the tap. In Fig. 30 (*a*) is shown one form of jig, consisting of a piece of iron or steel bent to the form shown at *a*. The bottom surface *b c* is planed flat, and a hole *d* the size of the tap shank is drilled square to *b c*. A plug *e* is turned to fit *d* and the hole *f* to be tapped. To use this tool or jig, the plug is put into the hole *d* and then pushed into *f*, as shown; the jig *a* is clamped fast at the point *g*, and adjusted until the plug *e* fits easily in both holes, after which the plug is removed and replaced by the tap,

which will be held in the correct position to tap the hole, as shown in (*b*). The hole *d* in the jig may be made as large as the largest tap, and a set of bushings made to adjust it to taps having smaller shanks.

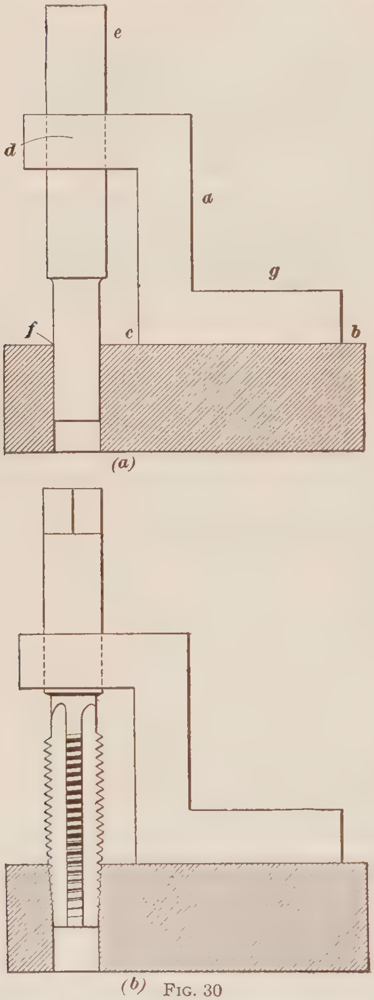


FIG. 30

51. Tapping Smooth Threads.—It is sometimes desirable to tap holes with particularly smooth threads. In the case of United States standard threads, this may be done by first tapping the hole with a **V**-thread tap and then following it with a tap having the United States standard form of thread. The **V**-thread tap will leave enough material so that the United States standard thread tap will perform the same work in the tapped hole that the hand reamer does in the plain hole. The use of plenty of lard oil will assist in producing a smooth thread in the tapped hole.

52. Number of Taps Necessary.—Holes in thin stock may be tapped in one operation by running the taper tap clear through the piece; but if the hole is of great depth, or the material is hard, a second, or plug, tap must be run down, to relieve the long cut made by the taper tap. By using these two taps alternately, holes may be tapped to any depth that the taps will reach. Neither the taper nor the plug taps will thread a hole clear to the bottom, so when this is necessary, a third tap,

called a *bottoming tap*, is screwed clear to the bottom of the hole. Care should be taken in using this tap, as the end teeth are easily broken by the heavy cut.

53. Pipe Threads.—The threads on pipe are of the **V** type, and to insure tight fits the threaded parts are made tapering. The standard taper for the threaded portion of pipe is $\frac{1}{16}$ inch to the inch or $\frac{3}{4}$ inch to the foot. The holes to be tapped for small sizes of pipe are usually drilled to the size of the bottom of the thread at the small end of the tap, and then the pipe tap is run down to the proper depth; but for the large work, a reamer having the same taper as the tap is run in to remove some of the stock. This reaming leaves the right amount of stock for threading, and saves unnecessary wear on the tap.

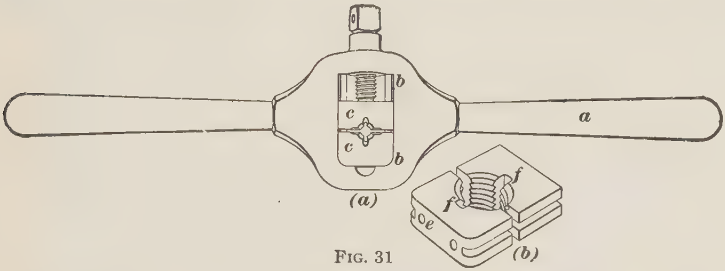


FIG. 31

Inside pipe threads are tapped a depth such that the large end of the threaded part of the standard pipe plug gauge will, when screwed into the tapped hole, be flush with the end of the fitting. Outside pipe threads are cut a depth such that one face of the standard pipe ring gauge will, when screwed onto the threaded portion, be flush with the end of the work. When standard plug-and-ring, pipe-thread gauges are not available, the pipe and fittings are threaded to fit the fittings and pipe on which they are to be used.

54. Die Stock and Square Dies.—Outside threads of various pitches and sizes must often be cut by hand. Dies for such work are made to cut threads on pieces ranging from $\frac{1}{16}$ inch to 2 inches in diameter. A form of stock and die is shown in Fig. 31 (*a*). The stock *a* has an oblong opening *b*

provided with guides for holding the split die c, which is closed by a setscrew. The form of these dies is shown in (b). They

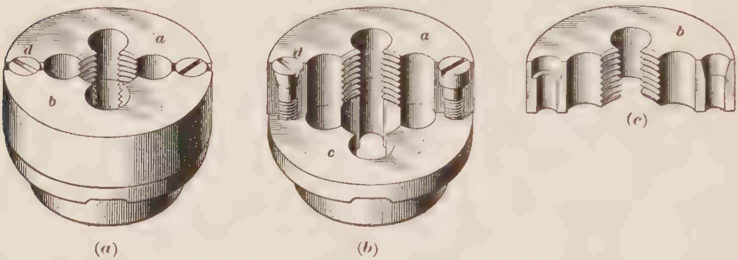


Fig. 32

are so constructed that the cutting is done at the points f, which also steady the dies when starting on the work. Bolts can be threaded standard, undersize, or oversize with these dies. For example, a No. 14 screw, a $\frac{1}{4}$-inch, or a $\frac{9}{32}$-inch screw, all 20 threads per inch, can be fitted with one pair of dies. They are made in several sizes and their cutting edges are provided with clearance. These dies are especially adapted to repair work where the variety of work is great and the quantity small. With them several cuts must be taken to cut a full thread. A pair of blank dies with suitable notches cut in them, used in this stock, make an excellent tap wrench.

55. Die Stock and Round Dies.—Standard work is usually done with any of the many forms of round dies, one of which is illustrated in Fig. 32 (a), (b), and (c). When in use, the die is held in a die stock, of the form shown in Fig. 33. The die is made of two parts a and b, Fig. 32 (a) showing the two parts in place; (b), the die with one part removed, the latter being shown detached in (c). This die can be adjusted

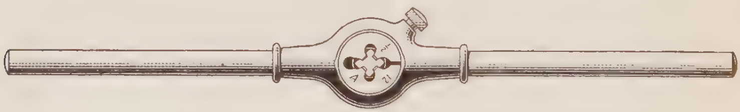
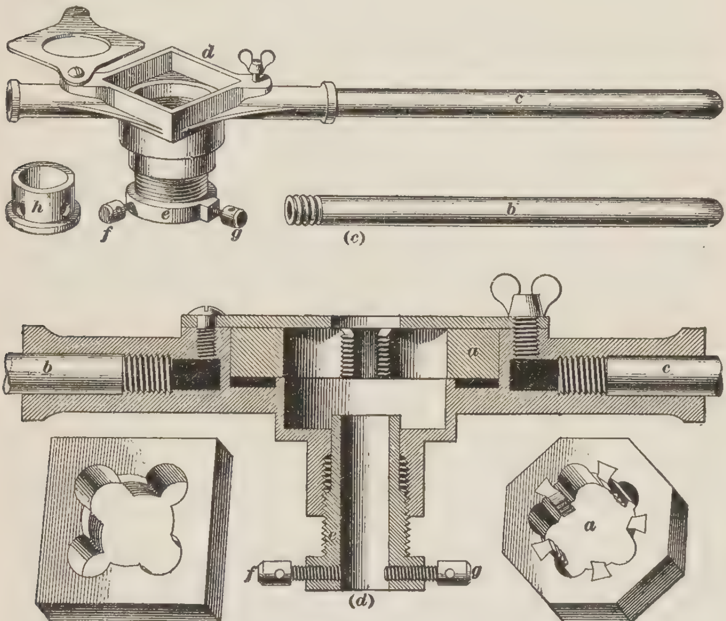


Fig. 33

within narrow limits, the screw d being made with a tapered head, and by turning it in, the two halves are forced apart.

56. The die stock, Fig. 33, is provided with a thumbscrew that grips the die when in place. The lower part *c*, Fig. 32 (*b*), of this die is bored out to the exact size of the rod to be threaded, and forms a guide for the die in starting. These dies require some pressure to start them; but once started they cut a full thread at one operation. The large sizes are made with inserted chasers that are adjustable for wear and if broken may easily be replaced.



(*a*) FIG. 34 (*b*)

57. Threading Pipe.—Pipework enters largely into some branches of machine work, and a few of the principal tools used in this connection will be illustrated and described. Pipe is made in lengths of from 15 to 20 feet. It is threaded on both ends at the pipe mill, and a sleeve screwed on one end. Large pipe has a ring screwed on the other end, to protect the threads during shipment and handling.

The pipe is cut to the correct length and is then ready for threading. The large sizes are usually threaded in power-

driven machines, and the small sizes are done by hand with one of the various forms of pipe dies.

58. Pipe Stock.—The ordinary pipe stock is shown in Fig. 34. The die *a*, Fig. 34 (*d*), is held in the stock into whose ends the handles *b*, *c* are screwed. The stock has a square recess *d*, Fig. 34 (*c*), in the top to hold the die shown in Fig. 34 (*a*). A cover slides over the die to hold it in place. For threading the larger sizes of pipe, the pipe stock is threaded internally and the bushing, or lead screw, *e*, Fig. 34 (*d*), is screwed into it. The thread on the bushing is $11\frac{1}{2}$ per inch for sizes from 1 inch up to and including 2 inches, and 8 per inch for sizes above 2 inches, to correspond to the standard pipe threads. A bush-

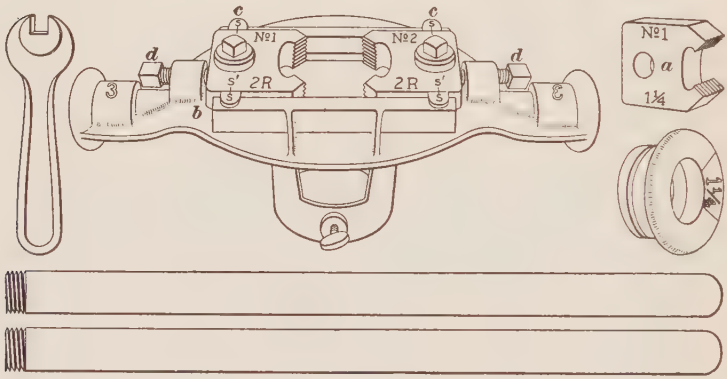


FIG. 35

ing, or thimble, *h*, Fig. 34 (*c*), having a hole through it of the size of the outside diameter of the pipe is placed in the bushing *e*, and the whole slid over the end of the pipe so that the cutting edges of the die rest on the end of the pipe. The bushing *e* is made fast to the pipe by the setscrews *f* and *g*, which pass through the holes in the thimble *h*, and the stock is given a few turns to start the die on the pipe, the screw thread in the stock acting the same as the lead screw in a lathe. As soon as the die has a good start, the setscrews holding the feed-screw may be loosened, and the work finished without using the feed-screw further. The small sizes of pipe are threaded in the same manner, but the die stock is made without the feed or lead screw.

59. Adjustable Pipe Dies.—An adjustable die, made in two parts, is shown in Fig. 35. The stock is provided with the usual handles for turning and the thimble for guiding the dies on the pipe. The dies *a* are held in the stock *b* by means of the clamp screws *c*, and are made to cut larger or smaller than the standard by the adjusting screws *d*. Lines *s* are cut in the stock, and corresponding lines *s'* are placed on each die, so that when these lines coincide the dies are set to cut pipe to the standard size. As these dies are more easily sharpened, they are considered decidedly superior to the solid ones.

LAYING OUT

PRINCIPLES

60. Laying out is the process of placing such lines on castings, forgings, or partly finished surfaces as will designate the exact location and nature of the operations specified in the drawing.

61. Preliminary Layout.—In many cases, one or more men are regularly employed in laying out work. Occasionally, the same men devote a part of their time to inspecting or testing finished or partly finished work. The inspection when partly finished is to prevent additional work, should the first operation be so defective as to call for the rejection of the piece. When the work is laid out by an expert who has the drawing of the finished piece before him, he may determine, before any work is done, whether the forging or casting has sufficient stock, and should stock be lacking at any particular point, the piece may either be rejected or perhaps saved by carefully locating the lines so as to permit the finishing of all the holes and surfaces; whereas, without the special laying out, it may afterwards be found that there is not sufficient stock for some later operation.

62. The economy of having the laying out done by men set apart for that purpose is due to several reasons. Men

become expert and quick at this kind of work; the tools of the shop are not idle while the men running them stop the machine to do the laying out, as was formerly the case; and the work can be laid out on a convenient plate with proper tools to better advantage than otherwise. Then, work can be laid out as soon as the castings or forgings come into the shop, perhaps long before the tools are at liberty to finish the work, and it may be of great advantage to find out early any lack of stock, or any defect that may cause the rejection of the piece, or any change that is to be made, if it is a forging. A casting may appear perfect, but a hole may be cored too large, or the core may not have been set correctly, or it may have moved in the mold. After laying out some of the lines and making sure that there is stock enough for finishing, it is often advisable to do part of the finishing before completing the laying out.

63. Divisions of Laying Out.—Laying out may be divided into two parts: the preliminary and the final. The preliminary laying out consists in measuring the piece to see that it is of the proper size and dimensions, and then drawing such lines on its surface as will show where the first machining operations are to be performed. The center lines are so placed, if possible, that they will not be removed by the machining process, and can be used in resetting the piece for future machining. In the final laying out such lines are placed on the machined surfaces as will indicate the further operations to be performed.

The preliminary laying out in the case of a steam-chest cover would be to level it on the table and draw such lines on its edges as will indicate its thickness; after which it should go to the planer and be machined to the dimensions denoted by the lines. The final laying out will consist of laying out the holes for the studs and such other operations as may be designated on the drawing.

64. Methods of Laying Out.—Laying out is done in different ways, according to the nature of the work and the accuracy required. The lines are drawn on the surfaces with surface gauges or scribers, and centers are denoted by prick-

punch marks. Circles and arcs of circles are drawn with dividers and trammels, and many irregular forms are drawn on the work from accurately filed templets.

In some cases, the work is laid out by simply drawing the necessary lines on its surface. In other instances, permanence is given the lines by dotting them with prick-punch marks placed directly on the line; or a thin chisel may be driven into the work on the lines, making a deep cut in the metal. Guard lines are often placed on the work to make sure that the original lines were closely followed, as, in laying out holes to be drilled, some machinists place a circle $\frac{1}{16}$ inch outside the one worked to, and if the hole is correctly drilled, it will be concentric with this circle.

65. Coatings on Which to Make Lines.—In many cases it would be impossible to scratch lines on an iron surface, especially when the surface is either not perfectly smooth or it is very hard. The use of various coatings, on which the lines may be made or in which they may be scratched is therefore necessary. Sometimes, chalk is simply rubbed on the surface. In other cases, powdered chalk is mixed with alcohol, or whiting is mixed with alcohol or water, and applied with a brush. Alcohol has the advantage over water in that it will dry quicker and has no tendency to rust the surface.

66. When the surface has been machined and is fairly smooth, it may be copper-plated by wetting and rubbing with a piece of copper sulphate (blue vitriol), or, better still, by making a saturated solution of copper sulphate and applying with a brush or swab. As the solution dries, the surface will be covered with a thin layer of copper. Surfaces to be thus coppered must be thoroughly cleaned and free from oil before applying the solution. Lines may easily be scratched in this copper and will show very plainly on account of the difference in color between the iron and the copper. A light coat of some quick-drying white paint is sometimes used, as, for instance, white lead and turpentine. After the lines are drawn, their location should be permanently established by means of light prick-punch marks.

LAYING-OUT TOOLS

67. A variety of tools are used in laying out work. The most common are the surface gauge, straightedge, scriber, hammer, prick punch, level, square, dividers, trammels, and a line, if large work is handled. In addition to these tools, there should be a supply of quick-drying white paint, chalk, a solution of blue vitriol, a lot of iron wedges, and small pieces of sheet metal of various thicknesses for blocking, parallels of various sizes, small screw jacks, one or more pairs of **V** blocks, a pinch bar, and a hack saw.

The surface of the laying-out table or plate must be kept

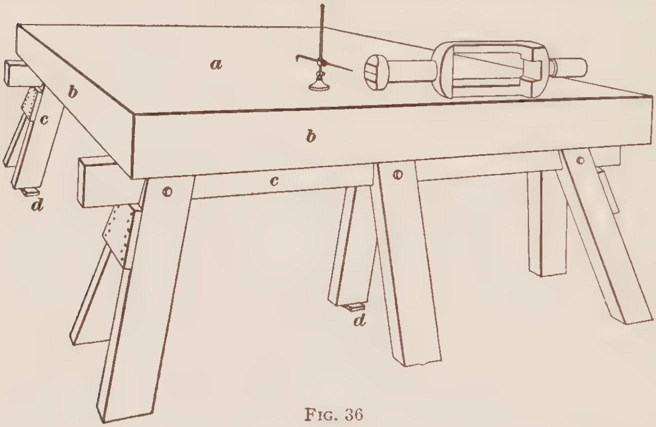


Fig. 36

as clean as possible; therefore, a bench brush should be provided for the table, and for the large plate, a brush and broom. As a good many drawings are used at the laying-out table, a table or stand of sufficient size to hold them, and drawers in which to place those not in constant use, should be provided near at hand.

68. Laying-Out Plate for Light Work.—For laying out light or small work, the size and character of the plate used may vary greatly. Fig. 36 illustrates a general form of laying-out plate. The plate *a* may vary in size from 2 or 3 feet on each side up, about 7 feet by 10 feet being the largest size

practicable for this design of plate. In the larger size, the top *a* should be made $1\frac{1}{4}$ inches thick, the ribs *b* should be carried around the sides of the plate, and cross-ribs placed across the back of the plate about every 24 inches; the depth of these ribs for a plate 7 feet by 10 feet should not be less than 8 inches, and they should be of the same thickness as the body of the plate. The casting should be planed on the upper surface *a* and on the faces of the ribs *b*, so that the faces *b* will be at right angles to the surface *a*, thus making it possible to use surface gauges or other tools from the faces *b*. Parallel lines should be drawn both lengthwise and crosswise of the plate, the lines being 3 or 6 inches apart. The plate is mounted on trestles *c*, and the upper surface of the plate should be kept level and out of wind, by adjusting wedges under the legs of the trestles, as shown at *d*. For ordinary working, the upper surface of the plate should be about 30 inches from the floor. Such a plate as this may be placed under the main traveling crane, and it is also well to have an auxiliary air lift, or similar hoisting device, for handling the work when the crane is not available.

69. The advantages of this style of plate are that it is not a permanent fixture, but can be easily moved from one part of the shop to another. Then, too, if the plate is not needed for some time, but the floor space is, the plate can be turned up on one edge and set against the wall.

The disadvantages are that owing to its support on trestles it is not suitable for laying off heavy work that requires great accuracy, owing to the fact that the plate cannot be kept true and out of wind when heavy weights are being placed on or taken from it, as the stresses on both the plate and the trestles are constantly changing. A plate of this general style is sometimes mounted on a concrete or brick foundation; but if this expense is to be incurred, it is usually best to have a more elaborate plate, such as is described in Arts. **70** and **71.**

70. Laying-Out Plate for Heavy Work.—For laying out heavy work, the plate must have a very firm foundation, and the ribs must be of such a depth that the plate will not spring under the weight of the piece being laid out. Plates

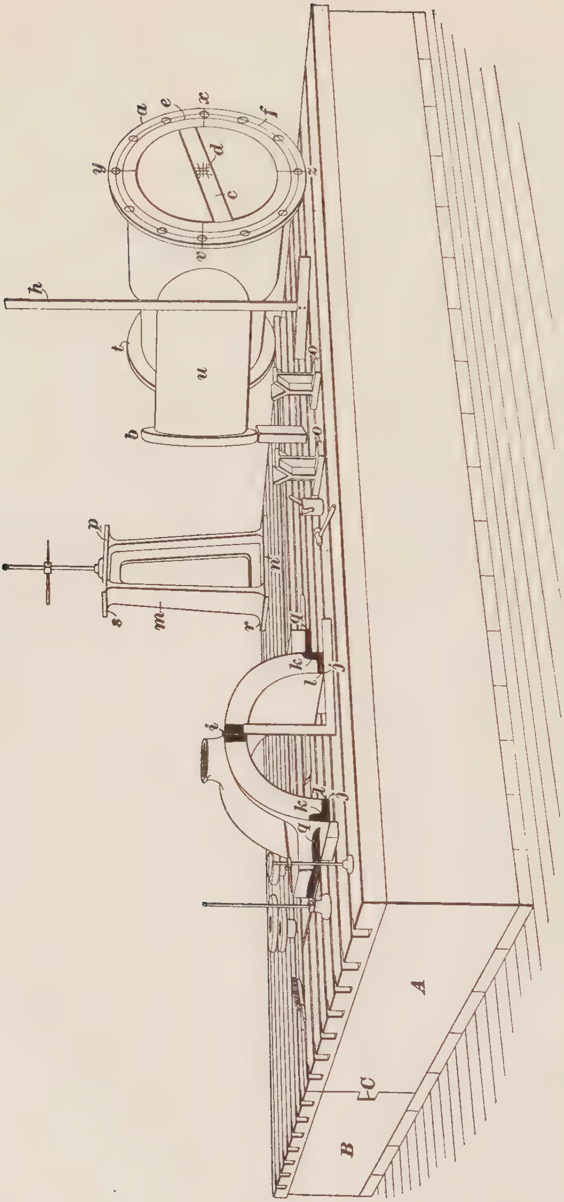


FIG. 37

for heavy work are usually made lower than those for light work, the top of the plate being placed from 18 to 24 inches above the floor. Fig. 37 illustrates a very good plate for heavy work. The top of this plate is 24 inches above the floor, and it is composed of two pieces *A* and *B* that are joined with a tongue and groove, as shown at *C*. This plate is 8 feet by 15 feet, and the ribs around the outside and along the center are made to extend clear to the foundation, which is only 2 inches above the floor, thus making the plate 22 inches deep. Parallel grooves 6 inches apart are planed the entire length of the top surface, and at right angles to these grooves, lines are ruled on the surface 6 inches apart. The grooves are especially handy, because parallels can be slipped into them and pieces brought against these parallels for lining up, after which measurements may be made from either grooves or lines. All heavy

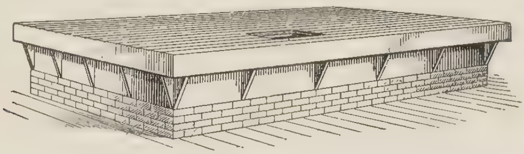


Fig. 38

plates should have a good bearing on the foundation, which should be made so deep and strong that it will not settle or be broken under any weight that is liable to be put on the plate.

71. Laying-Out Plate for General Work.—In shops handling a variety of work, varying from heavy to light, a plate of the form illustrated in Fig. 38 may be used. This plate is about 8 feet by 12 feet. The foundation consists of a concrete base, Fig. 39, on which are built three brick walls running lengthwise of the plate and a cross-wall at each end. The plate is supported on these walls, as shown in Fig. 39. A hole in the plate, at least 18 inches by 24 inches, together with an opening in the middle wall, affords access to the space beneath the plate for the purpose of cementing between the iron and brickwork. This hole in the plate is also useful, because it permits parts of the work to hang below the surface; as, for instance, one crank of a three-throw crank, or an arm on a rocker-shaft.

The hole is cast with a ledge to receive a wooden cover, which prevents objects from falling through the hole and being lost under the plate. The top of the wooden cover should be $\frac{1}{8}$ inch below the surface of the plate. The plate overhangs the foundation 7 inches all around, to allow foot-room on the floor.

72. Grooves $\frac{1}{2}$ inch wide and $\frac{1}{4}$ inch deep are planed lengthwise every 6 inches, and lines made crosswise every 6 inches; or grooves may be planed both lengthwise and crosswise. A number of short parallels $\frac{1}{2}$-inch square should be provided to drop into the grooves to aid in locating the work or tools.

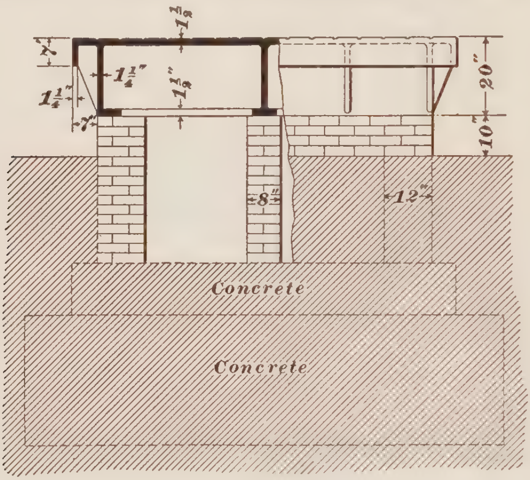


FIG. 39

The proportions or size of the plate may be varied to suit the character of the work being done. It is not good practice to mount a plate on brick walls all running in one direction, when heavy work is to be placed on or taken off the plate; for if work were to strike the end, there would be danger of racking the walls, while the tying of the longitudinal walls together at the ends tends to overcome this difficulty, and also prevents dirt from collecting beneath the plate.

73. Revolving Laying-Out Plate.—In many cases the light must fall on the work from a certain direction, to enable the operator to see the lines being drawn; also, in the case of

small work, it is often necessary to operate on several sides of the piece. If placed on a large plate, this work would have to be turned and reset several times, or the operator would have to climb over the plate. To overcome this difficulty, a revolving plate of the general form shown in Fig. 40 may be used.

74. This plate consists of a circular table *a* mounted on a suitable foot, or base, *b*. The back of the plate *a* is ribbed,

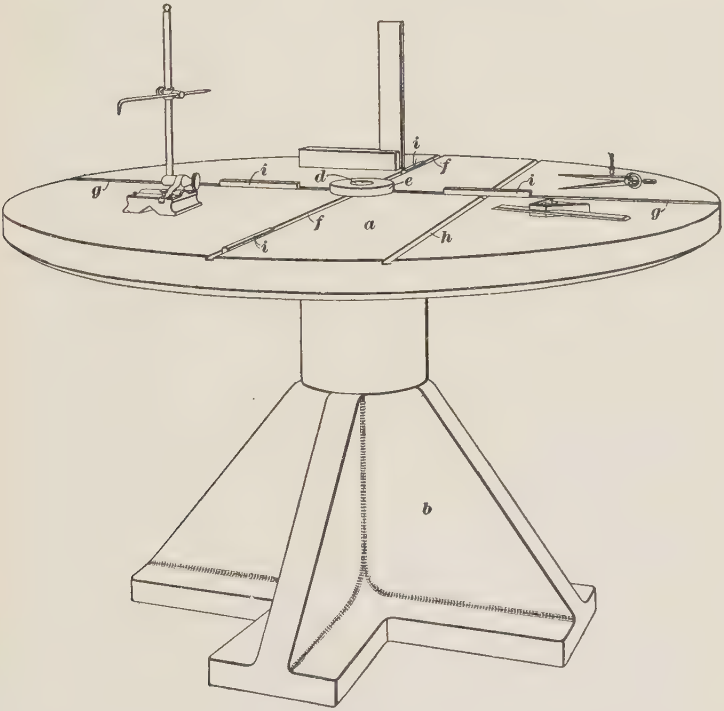


Fig. 40

as shown in Fig. 41, and a ball bearing is inserted between the plate *a* and the base *b*, as shown at *c*. To facilitate the centering of work having a hole in it, a plug *d*, Fig. 40, may be inserted in the center of the table and a ring *e* of suitable diameter placed over the plug. Work thus dropped over a ring of the proper size can be quickly centered. To facilitate the dividing of

work, two grooves *f* and *g* are planed across the table at right angles. One edge of each groove passes through the center of the table. For convenience in measuring, other grooves may be located at any specified distance from the center, and parallel to either one of the main grooves, as shown at *h*. Small parallels are frequently inserted into the grooves when setting squares or other tools, or as a stop to locate the work in the desired position. These parallels are shown in position at *i*.

75. The top of the table illustrated is 31 inches above the floor, and the rim is 2 inches thick. For some classes of work it is convenient to have circular lines, 1 inch apart, turned on the table before the plate is taken from the lathe. This form of table can be easily taken to the work, in place of bringing the work to the table, in cases where there is a large amount to be handled, and especially when it is advantageous to have it

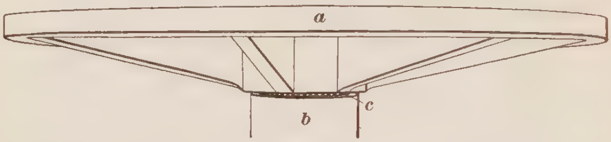


FIG. 41

done near the same machine. For convenience in moving the table, an extension of the hole that receives the pin *d* in the base *b* may be tapped, and a strong eyebolt fitted to it. This bolt will form a ready means of attaching the crane hook to the table.

76. Special Laying-Out Appliances.—On the laying-out table illustrated in Fig. 37 are shown several special laying-out appliances. First may be mentioned the parallel shown at *m*. These parallels are made in various heights, differing by even feet, and smaller solid parallels or hollow rectangular parallels are made, varying by inches, so that any height varying by inches can be obtained from a series of them. The edges *n* and *p*, and *r* and *s* should be in the same vertical planes, so that when one of the edges *n* or *r* is brought against a certain parallel or line on the plate, the corresponding edge *p* or *s* will be in the same vertical plane. The man doing the work

is thus enabled to obtain horizontal measurements from the edges of the upper surfaces of the parallels. With the use of these parallels, it is unnecessary to use the old-fashioned high surface gauge, which could never be depended on because of the spring of its parts.

77. At the front of the plate are shown two **V** blocks *o* that are extremely useful in laying out pieces having turned ends, or any form that must be supported in this manner. At *h* is shown a special **T** square, which, for some classes of work, is more useful than an ordinary square for drawing vertical lines, owing to the fact that there is little, if any, danger of the portion in contact with the plate becoming displaced; while if an ordinary square were used, the arm or beam in contact with the plate must be made very heavy to balance the long blade.

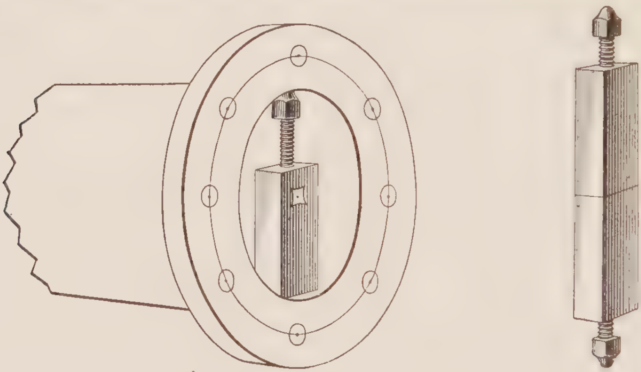
EXAMPLES OF LAYING OUT

78. Locating Centers of Circles.—When it is necessary to draw a circle, the center of which falls in an opening or cored hole, a strip of wood, or other material, must be fitted across the opening, and the center located on it. As wood is too soft to give a good center to work from, it is usual to place a piece of metal on it where the center is required. This piece of metal may be a tack driven into the wood, the center being located on the head; or a triangular piece of tin having the corners bent at right angles to the surface, so that they can be driven into the wood, the center being located on the flat surface of the tin.

79. Use of Screw Jacks.—Small screw jacks having flat sides on the body of the jack are sometimes used to locate centers, the screw jack being placed across the hole and the center located on its side, as shown in Fig. 42 (*a*). After the center is located, the bolt-hole circle is drawn, and the required holes spaced off on it. If the cored hole is too large for one screw jack to reach across, two screw jacks may be placed with their bases together, as shown in (*b*), and the center located on them.

80. Laying Off Subdivisions of Circle.—When a circle is to be divided into 4 or 6 parts, or into multiples of 4 or 6 parts, it is usual to draw diameters dividing it into this number of parts first, and then make any additional subdivisions from these points. Four divisions can be easily obtained by drawing two diameters at right angles, the work being mounted on the laying-out plate, the horizontal diameter being obtained with the surface gauge, and the vertical one by means of a square.

81. To lay off six divisions, set the dividers equal to the radius of the circle and then step them around the circumference of the circle, when it will be found that the radius will make six equal divisions. To determine the dimension to which the dividers must be set to lay off any other number of divisions, up to and including 100, Table I is given. By its use, the dividers may be set very closely, and much of the time and trouble usually spent in getting the dividers properly set by stepping them around with trial distances may be avoided. The numbers in the column headed N indicate the number of divisions into which the circle is to be divided, and the numbers in the column headed S are the factors that, when multiplied by the diameter, expressed in inches, of the circle to be divided give the measurement to which the dividers must be set to lay off the required number of subdivisions of the circle.



(a) (b)

FIG. 42

Example.—If it is required to divide a 62-inch circle into 44 equal parts; what will be the distance to which the dividers should be set?

TABLE I

FACTORS FOR FINDING DIMENSIONS FOR DIVIDING CIRCLES

N	S	N	S	N	S	N	S
1		26	.120540	51	.061560	76	.041325
2		27	.116090	52	.060379	77	.040788
3	.86603	28	.111970	53	.059240	78	.040267
4	.70711	29	.108120	54	.058145	79	.039757
5	.58779	30	.104530	55	.057090	80	.039260
6	.50000	31	.101170	56	.056071	81	.038775
7	.43388	32	.098018	57	.055089	82	.038303
8	.38268	33	.095056	58	.054139	83	.037841
9	.34202	34	.092269	59	.053222	84	.037391
10	.30902	35	.089640	60	.052336	85	.036953
11	.28173	36	.087156	61	.051478	86	.036522
12	.25882	37	.084804	62	.050649	87	.036103
13	.23932	38	.082580	63	.049845	88	.035692
14	.22252	39	.080466	64	.049068	89	.035291
15	.20791	40	.078460	65	.048312	90	.034899
16	.19509	41	.076549	66	.047582	91	.034516
17	.18375	42	.074731	67	.046872	92	.034141
18	.17365	43	.072995	68	.046184	93	.033774
19	.16460	44	.071339	69	.045515	94	.033415
20	.15643	45	.069756	70	.044865	95	.033064
21	.14904	46	.068243	71	.044232	96	.032719
22	.14232	47	.066793	72	.043619	97	.032381
23	.13617	48	.065401	73	.043022	98	.032051
24	.13053	49	.064073	74	.042441	99	.031728
25	.12533	50	.062791	75	.041875	100	.031411

Solution.—Opposite 44 in the column marked N of the table, and in the column marked S, is found .071339. Multiplying this factor by the diameter of the circle, the required distance is found to be

$$.071339 \times 62 = 4.423018 \text{ in.} \quad \text{Ans.}$$

For ordinary work it would not be necessary to set the dividers closer than to hundredths of an inch; hence, the dividers may be set to 4.42 inches. Since 44 is divisible by 4, the circle may be divided by two diameters drawn at right angles, and the spaces marked off from the four points thus obtained.

82. Reducing Error When Subdividing Circles.—It is always best in laying off divisions of a circle to locate either 4 or 6 points accurately, when possible, and to work from these, as this reduces the effect produced by means of a slight mistake in the setting of the dividers; for if the circle were all laid off from one point, and the dividers were set to a distance slightly greater than that required, the last division would be smaller than the others by an amount equal to this error multiplied by the whole number of spaces in the circle. But by dividing the circle into 4 or 6 parts, and then stepping off the spaces each way from each of these points, the total error at any given point will only amount to the error in setting the dividers multiplied by the number of spaces marked off from the given point.

83. Laying Out Bolt Holes for Pipe Flanges.—In Fig. 37 at the right-hand side of the plate is shown a casting for a branch pipe in which it is required to lay out bolt holes for the different flanges. The pipe is leveled by blocking up the small end *t* until the large end *a* stands square with the plate or table. The branch, or arm, *u* is next raised until the surface *b* is square with the table. Wooden strips are fitted across the ends of the pipe, as shown at *c*, this fitting usually being done before leveling up the pipe, so as not to displace the setting by driving in the wooden strips. After the wooden strips are in place and the pipe is leveled up, the trammels are set to approximately the radius of the circle *c* that has been turned on the end of the pipe while in the machine. With these trammels, the arcs at *d* are drawn and a center located between them. Usually, a small piece of tin or other metal is placed at the center of the wooden strip, to receive the center when located. After this, the trammels or dividers are set to the radius of the bolt circle *f* and this circle is drawn.

84. If the drawing calls for an even number of holes, a surface gauge is set to the center and a line drawn across the flange, as shown at *v x*. This line may be continued across all three of the flanges. If the number of holes is a multiple of 4, a vertical line is also drawn by means of a square, or a **T** square similar to that shown at *h*, thus locating the top and bottom holes *y* and *z*. The other holes are spaced off from these by means of dividers. In case of any number of holes, whether odd or even, the setting of the dividers can be obtained by the method described in Art. **81.** In Fig. 37, 12 holes are shown in the flange *a*. When the holes in the three flanges must have

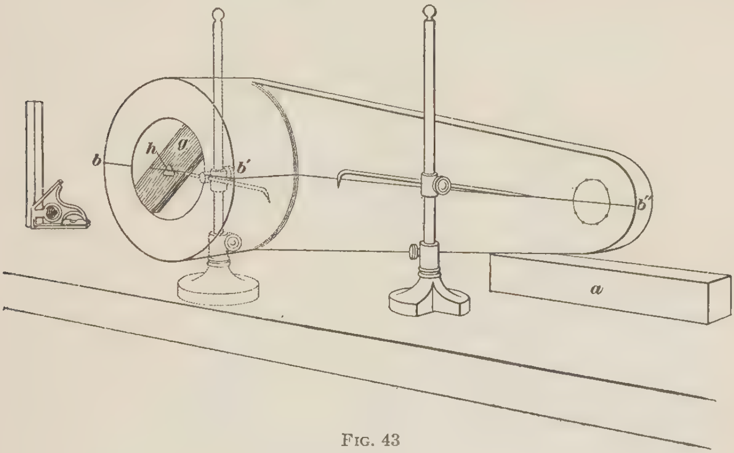


FIG. 43

some fixed relation to one another, the horizontal line *v x* is carried around all three faces, and the holes laid off from this as required.

85. Laying Out Large Journal Cap.—At the left-hand corner of the plate, Fig. 37, is shown a journal cap in the process of being laid out. The casting is blocked up on the plate so that the front and back faces are approximately square to the surface, and the center line *i* is drawn midway between the points *j*. The shoulders *k* are laid off at equal distances from the center line *i*, and a proper allowance for finish is made at the top of the bearing, after which the lines *l* are drawn, so that

the vertical distance from the horizontal plane passing through l to the point determined at the top of the bearing is equal to the radius of the finished bearing. The lines q on the flanges of the cap are next drawn the proper distance above the lines l. After this, the cap is planed before the holes for bolting down the cap are laid out or drilled.

86. Laying Out Crank-Arm.—The crank-arm shown in Fig. 43 may be laid out as follows: The piece is first placed

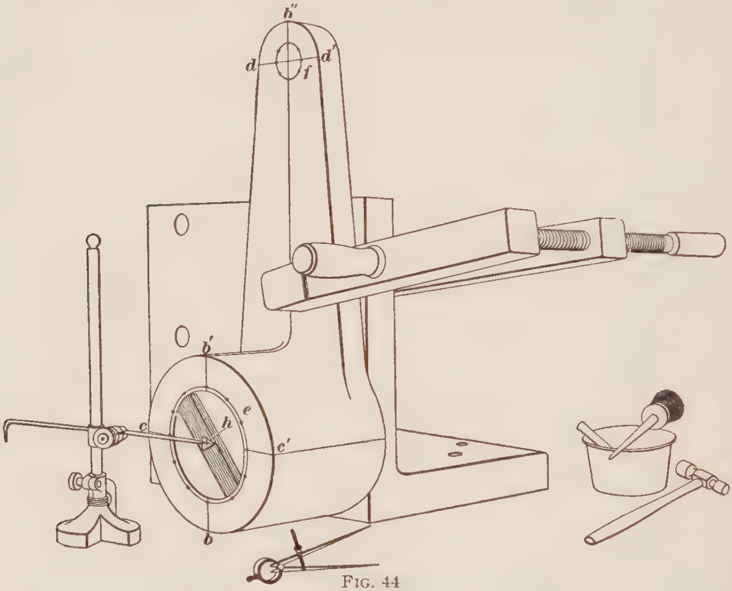


FIG. 44

on its side, with the parallel a under the small end. A surface gauge is set to the center of the hub, which has been determined by placing a wooden strip g across the hub and locating a center h on it by means of dividers. After this, the parallel a is pushed under the end of the arm until the small end is raised so that the point of the dividers is level with the center of the arm. Then the line $b\,b'\,b''$ is drawn. After this the arm is clamped to an angle plate, as shown in Fig. 44, the line $b\,b'$ being brought vertical by means of a square. The surface gauge is set to the center h and the line $c\,c'$ drawn. Substitut-

ing a longer spindle in the surface gauge, it is next set so that its point will be above the line $c\,c'$ an amount equal to the distance between the two holes in the arm, and the line $d\,d'$ is drawn. This locates the center of the hole f, after which the circles at e and f may be drawn with dividers and marked off with prick-punch marks, as shown, ready for drilling or boring.

87. Laying Out Crosshead.—The method of laying out a crosshead is governed principally by the design of the crosshead. The form shown in Fig. 45 is one provided with adjustable shoes, the end $h\,h'$ of the crosshead being con-

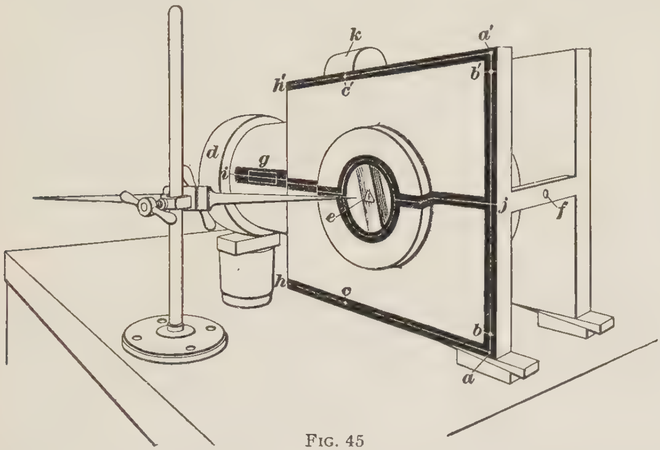


FIG. 45

siderably narrower than the end $a\,a'$, so that as the shoes are moved along on these inclined surfaces they will be expanded. The method of laying out is as follows: The crosshead is placed on the table, with blocking under the piston-rod end, and wedges under both sides of the connecting-rod end, as shown in the illustration. If the piston-rod end is to be turned at the part marked d, the casting is usually made with a metal bridge f, which is cut out after the rest of the machine work has been done. If no such metal bridge exists, a wooden strip must be inserted at this point on which to locate the center f. Wooden blocks are also placed in the holes, as shown at e, and in the center of the piston-rod hole in the end d.

88. Chalk or white paint is applied in a broad line wherever the laying-off lines are to be placed, as shown by the broad, dark marks in the illustration. The centers of the holes for the connecting-rod pin and for the piston rod are now found, and the casting is leveled up by them and brought square with the table at the connecting-rod end. If the cored holes for the piston-rod or crosshead pin are not in the correct relative position, the body of the casting may be shifted somewhat, to bring them into such a location that all can be finished to the required dimensions. When these points are definitely located, the center line $i\,j$ is drawn on all sides of the work. The centers at each end of the crosshead pinholes e are laid off the proper distance from the piston-rod end d, and a circle is drawn at each end of the crosshead pinhole. A circle is also drawn for the piston-rod hole. The slot g for the piston-rod key is next laid off the proper distance from the end d. This slot is sometimes made with round ends and sometimes with square ends, depending on the conditions specified in the drawing.

89. The line $a\,a'$ is drawn the correct distance from the center e, this line being located by means of a square that is set on the table. The lines $a\,h$ and $a'\,h'$ are not parallel to the table, on account of the tapered form of the crosshead body, and in order to determine these lines, the following process may be used: The taper is usually given as so much per foot on the drawing, and this amount may be marked off from a and a', as shown at b and b'. After this, short vertical lines are located at c and c', 1 foot from the line $a\,a'$, and the surface gauge is set to the point b, and a mark made at c. It is then set to b', and a mark made at c', thus establishing two points on the inclined lines. After this a straightedge may be laid through the points a and c and the line $a\,h$ drawn, and then through the points a', c' and the line $a'\,h'$ drawn. The lugs k must be drilled for screws to operate the crosshead shoes. These screw holes may be located by drawing horizontal lines on the piston-rod end of the lugs by means of the surface gauge. These lines must be the proper distance from the center line

of the crosshead. After this, the center of the lugs may be found by means of dividers, and the circles representing the holes laid out.

90. Laying Out Engine Bed.—The method of laying out an engine bed differs according to the type of bed, but the essential features of the process are the same. Usually, the work has to be done in two or three operations, as some of the surfaces must be machined before the last part of the laying out can be done.

The bed chosen for illustration is shown in Fig. 46, and is of the solid cast type, having bored guides, the bearing for the crank-shaft being cast solid with the bed and the cylinder being arranged to bolt to the end of the bed. The bed casting *a* is placed on the laying-out or machine table, right side up, with blocks under it at intervals, as shown at *b*, *b*. Wooden strips are fitted across the ends of the guides, as shown at *r*, and across the sides of the jaws for the crank-shaft bearing, as shown at *c*. The centers of the guides are located on the wooden strips at both ends, and those of the jaws at both sides. The bed is now tested with the surface gauge, and set level by driving wedges between the bed and the blocks *b*. If either of the points located does not come true, the centers may be shifted slightly, care being taken to allow stock enough so that the guides and the jaws of the main bearing can be finished. Some beds of this type have their bottoms planed. If the bottom is not to be planed, it should be left as nearly parallel with the center line *d d* as possible. After having adjusted the centers of the guides and the jaws so that they all come level, and so that there is sufficient stock for finishing these parts, a surface gauge is set to the height of the center of the guides, and the line *d d* is drawn on painted strips or spots on both sides and ends of the casting. If the bottom is to be planed, the line *f f* should be drawn parallel to *d d*, and at the proper distance from it. After this, circles are drawn on the ends of the guides, using the centers in the blocks *r*. These blocks are then removed, and either a piece of piano wire or a sea-grass fish line *e e* is stretched through the guides. Each end of this

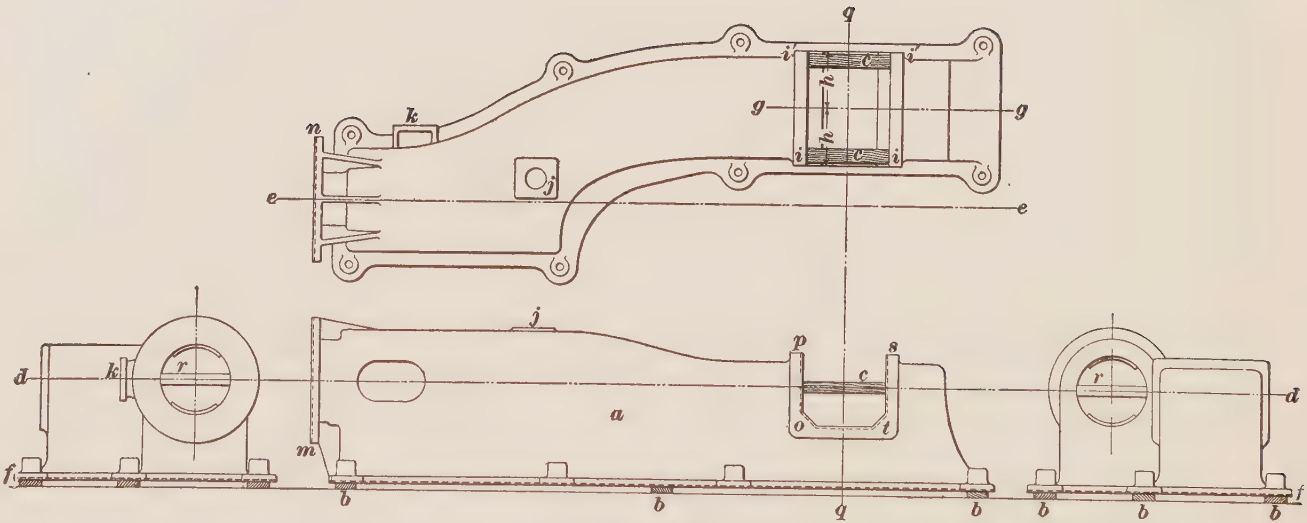


Fig. 46

line is secured to an upright and adjusted until it is located centrally with the circles scribed on the ends of the guides. The distance from this line *e e* to the center of the crank-shaft bearing is obtained from the drawing. A square is then brought against the line *e e*, and measuring from the square, the line *g g* is marked on the top of the jaws of the bearing. The distances *h* are obtained from the drawing, and the lines *i i* and *i′ i′* are drawn so as to determine the amount of stock to be removed from each end of the bearing.

91. The height of the governor pad from the bottom of the bedplate is marked off at *j*, and the amount to be removed from the rocker-arm hub is laid off at *k*. After this, the end of the bed to which the cylinder is to be bolted is also laid off, the line *m n* being drawn, thus determining the amount to be faced from this end. The distance from the end of this face

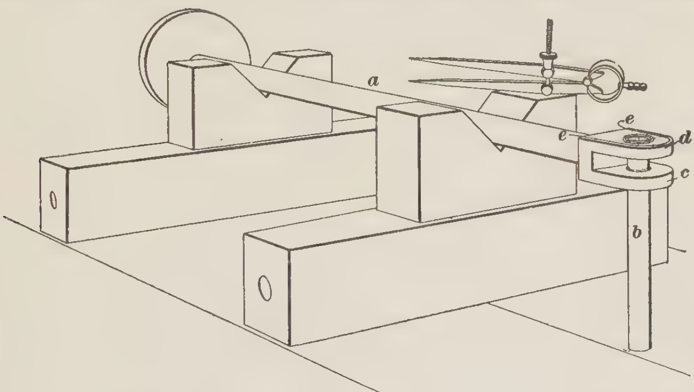


FIG. 47

to the center of the bearing should agree with the drawing. Most of the faces already determined must now be machined, after which the lines *o p*, *s t*, and *o t* may be laid off on the jaws of the bearing, and the center of the rocker-shaft hub at *k* may be laid off the proper distance below the center line. After the guides are bored and the end faced off to the line *m n*, the bolt circle may be drawn on this end, and the bolt holes laid out in a manner similar to that described for the laying out of bolts and flanges in Art. **83**.

If the laying out is done on a table having lines running both lengthwise and crosswise, it will simplify matters to adjust the bed so that some one line corresponds with the center line *e e*, after which many of the measurements may be obtained from the other lines.

92. Laying Out Ends for Small Rods.—A convenient method of laying out the ends of small rods is shown in Fig. 47, where the piston rod *a* is placed on **V** blocks that bring it level. A stake or post *b* is put into a hole in the plate or table, to which it has been fitted, so that it stands perpendicular, as shown, with its upper end through the holes in the fork *c*, fitting it accurately. The top end of the post *b* has a small center-punch mark in it, which provides a convenient center from which to draw the circle *d* for the rounded end of the fork. After the fork has been revolved to a vertical position and set to a square, the parallel edge lines from *e* tangent to this circle are drawn by means of a surface gauge.

ERECTING

(PART 1)

ERECTING TOOLS AND APPLIANCES

INTRODUCTION

1. **Erecting** is the putting together, assembling, or building of a whole from its parts. It refers to any mechanism or apparatus of appreciable size, such as an engine, dynamo, machine, or other mechanical device commonly used in the various engineering industries. It may be said to be divided into two classes: *shop* and *field erecting*.

2. On the completion of the parts of any mechanism, it is customary to assemble these together in the shop where they have been built, in order to test the device as a whole. When such shop tests have been satisfactorily carried out, the mechanism is next usually disassembled into parts or units of convenient size and packed ready for transportation to its destination. This first assembly is called **shop erecting.**

3. After arrival at its destination, the several parts or units are once more assembled or erected as a whole, the mechanism, however, being placed this time in its final working position; it is again tested, and, if the conditions of the contract have been met, is delivered to the purchaser. This second assembly is called **field erecting.**

The parts forming the complete mechanism are sometimes shipped direct to their destination without first being assembled and tested in the shop where built. When this is done, however.

it is usually owing to extraordinary conditions, such as lack of time in the fulfilment of a contract, inadequate assembling or testing facilities, too great expense, or to duplicate apparatus having already been built so that there is full assurance that all parts will go together without any preliminary fitting or adjusting.

4. The tools and appliances used in erecting are those employed in bench, vise, and floor work, together with pinch bars, rollers, blocking devices, hoists, trucks, etc.

PINCH BARS, ROLLERS, AND BLOCKING DEVICES

PINCH BARS AND ROLLERS

5. A **pinch bar** is an iron or steel bar used to pry up or move heavy objects. The most common form of pinch bar, Fig. 1 (*a*), is a straight bar, one end of which has a flat, wedge-shaped point turned slightly to one side, and the other end

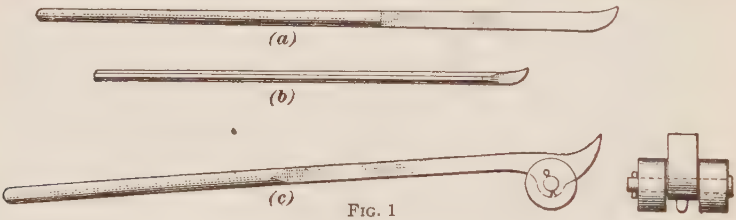


FIG. 1

of which is round and slightly tapering to form a handle. This form of bar is usually about 4 to 6 feet long. The smaller pinch bars are from 2 to 4 feet long, and are made of $\frac{5}{8}$-inch or $\frac{3}{4}$-inch octagonal steel, as shown at (*b*).

A rather convenient form of pinch bar that is well adapted for lifting and moving quite heavy weights is illustrated in Fig. 1 (*c*). The bar is mounted on two wheels, and consequently, when it supports a heavy weight, the bar and weight can be easily shifted.

6. **Rollers** are cylinders, either of wood or metal, and of various diameters and lengths, which are placed under a piece

of apparatus, thus enabling it to be readily moved for short distances. When metal rollers are used and the weight of the apparatus is not too great, they are generally made of pipe, not only because they are lighter and cheaper in cost, but also because they are more easily kept in alinement when in use either by inserting a bar and moving them, or by hitting them with a sledge.

BLOCKS AND TRESTLES

7. Any material or device employed in temporarily supporting work in process of erection, is known as *blocking*. The purpose of such supports is either to aline the work in some particular manner, to raise it into a certain position, or to move it in a given direction so that the assembling or erecting may be the more readily accomplished.

The form of the blocking depends on the class of work on which it is used and the service it is intended to perform. Frequently both the simplest and the most elaborate blocking devices are used advantageously on the same piece of work. Among the simpler forms may be mentioned *wooden blocks*, *iron blocks*, and *trestles*, or *horses*, while the more elaborate forms include various kinds of *screw jacks*, *ratchet jacks*, and *hydraulic jacks*.

8. Wooden Blocks.—Wooden blocks are used to a considerable extent in assembling even the heaviest apparatus, especially in the field where facilities for erecting are, as a rule, not so good as in the shop in which the apparatus is built. The blocks are usually square in cross-section often as large as 14 in. × 14 in. and of length varying from 1 to 6 feet. When blocks of this kind are to be used only once and then discarded, soft wood, such as pine, is generally selected; but if for constant service, hard wood, like oak or hickory, is to be preferred. Sometimes small wooden blocks or wedges are used for leveling apparatus on its foundation before grouting, or cementing, it in position. Hard wood should always be employed for this purpose, and the blocks should be so placed that the grain is at right angles to the pressure.

9. Iron Blocks.—Iron blocks are used more frequently in the shop than in the field, as they are more permanent and keep their dimensions better. Their greater weight is not a factor to be considered, since they are not transported great distances as in field erecting. When blocks are piled on top of one another in service, provision is sometimes made against slipping by means of slots or holes in the blocks into which **T** bolts or dowel-pins are inserted to lock adjacent blocks together.

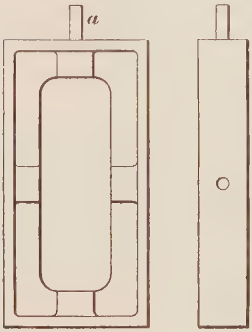


FIG. 2

The simplest and the most common forms of iron blocking are large parallels used in connection with machine tools. Large *parallels*, or *parallel blocks*, as they are often called, are usually made hollow, and are well ribbed in order to safely carry the great weight often placed upon them. *Cylindrical blocks* are also largely used.

10. Two excellent styles of parallel iron blocks are shown in Figs. 2 and 3. The form of the block shown in Fig. 2 combines considerable strength with lightness. It is planed all over so that opposite sides are parallel and adjacent sides are at right

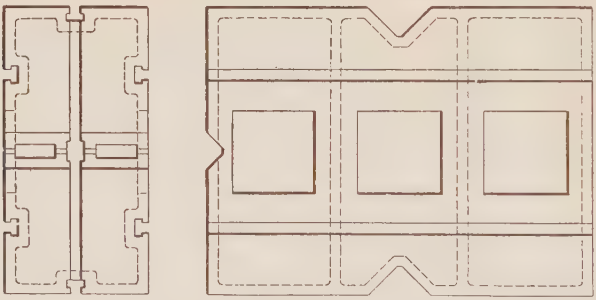


FIG. 3

angles. When a number of such blocks are made, it is advisable to make their corresponding dimensions equal, in order that the blocks may be used in pairs. The block shown in Fig. 2 is so constructed that a number of equal blocks may be piled up

to suit the requirements of the work and then form practically a single block. Holes for dowel-pins are drilled in corresponding positions in the four faces of each block. The dowel-pins are made a good fit; they prevent the blocks from slipping on each other and at the same time permit them to be readily separated. One of the dowel-pins is shown at *a*.

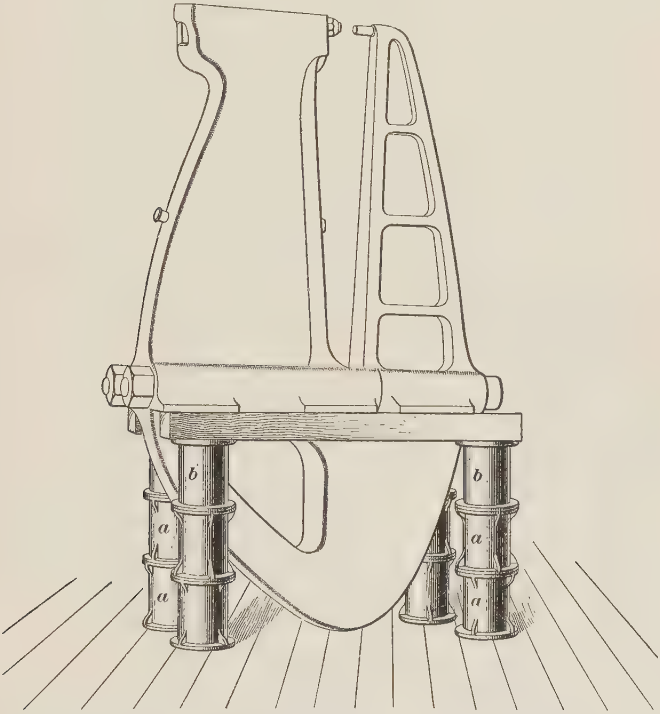


Fig. 4

11. The block shown in Fig. 3 has the general form of a box; it is finished all over and is provided with **T** slots and **V** grooves, as shown. The **V** gooves in the sides permit the block to be used with either side up for round work; the **T** slots allow the work to be fastened to the block, or the block to be secured in position by bolts. Blocks of this type may be used singly, or they may be piled up to any height that the work may require.

12. Cylindrical iron blocking, which is quite convenient for some classes of work, is shown, together with its application to a piece of work, in Fig. 4. The blocking resembles a short section of flanged cast-iron pipe; the sections may have the flanges strengthened by ribs, as, for instance, the sections *a*; or, the flanges may be plain, as those of the sections *b*. The flanges should be faced straight and parallel with each other, and the different sections should all have the same length.

A lighter form of pipe blocking is made of wrought iron or steel pipe that is threaded at both ends to receive flanges. The latter should be faced after they are screwed on the pipe.

13. Trestles.—The trestle is used as a support for large, but comparatively light, work. It may be made as is shown in Fig. 5. The legs should be cut so as to leave a shoulder *a*, and should be bolted to the beam *b* by bolts passing through the legs and the beam. When constructed in this way all the stress does not come on the bolts. When great stiffness is desired, or when the weight to be supported is rather heavy, the legs may be tied together near the bottom by boards nailed across them.

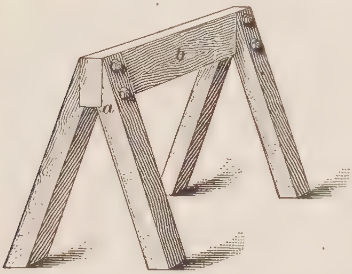


FIG. 5

JACKS

14. In addition to the parallel blocks just described, the lifting device known as a **jack** is almost indispensable in all kinds of floor work, especially in erecting. Jacks are made in a large variety of styles and sizes, from those intended for leveling up light work on the tables of machine tools to the heavy screw jacks and hydraulic jacks capable of raising or supporting 500 tons or more. They are used for a wide range of work.

15. Simple Leveling Jack.—The simplest form of jack consists of a circular cast-iron foot *a*, Fig. 6, which is faced at

the bottom and has a tapped hole through it. A square-headed screw *b* with a slightly rounded top, as shown, is used for raising the work. This style of a screw jack is employed principally in leveling up work on the tables of machine tools, although it will be seen later that similar jacks are sometimes made in large sizes and used in erecting.

When in use these jacks are set on the table of a machine tool in their proper positions; the work which is to be machined is then placed on them and leveled with the aid of a level or other device, the screws being turned up or down as required by means either of a wrench applied to their heads *b* or by a bar thrust through the holes *c*.

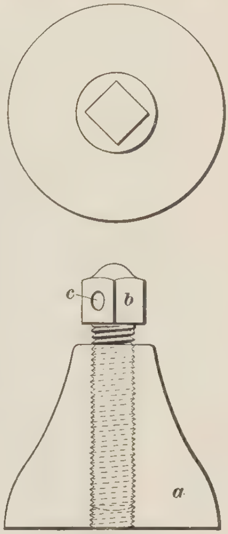


FIG. 6

16. Adjustable-Top Leveling Jack. A small jack, with an adjustable cap, which is very serviceable for machine-tool work and light assembling, is shown in Fig. 7. The body *a* is tapped to receive the adjusting screw *b*, which has a square top and holes for the rod *c*. The cap *d* is attached to the screw by a ball-and-socket joint, so as to permit the cap to accommodate itself to the angle of the work. When a solid or conical top is more

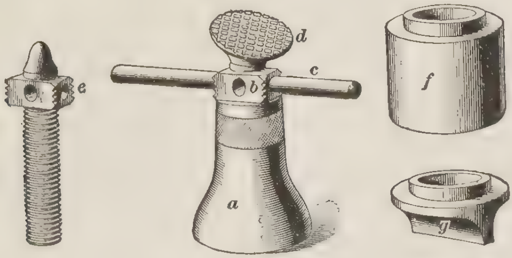


FIG. 7

suitable for the work, a second screw *e* is substituted for *b*. The foot of the body *a* is counterbored to fit the projection on

the auxiliary base f, which may be placed under the jack when a greater height is required. Auxiliary bases of different heights may be used as needed. A special base g is used where a good footing for the larger base cannot be obtained.

FIG. 8

17. Screw Lifting Jack.—When jacks are required for lifting, a different design with a greater screw travel becomes necessary, of which Fig. 8 is an illustration. The head of the screw is made with a cast-iron cap a that rests on a solid collar b; the upper end of the screw is turned down to pass through the cap and is beaded over to prevent the cap from coming off. A round bar inserted in the holes at b is used to turn the screw.

18. The jack shown in Fig. 8 can be used with a straight handle only where the screw can be turned through an angle of at least 90° at each setting of the bar. By bending one end of the bar through an angle of $22\frac{1}{2}°$, and inserting the bent and straight ends alternately, the angle through which the screw turns for each insertion of the bar is greatly reduced. The jack can thus be operated in a comparatively narrow space; but the constant resetting of the bar consumes so much time that this method becomes objectionable where much work of this kind is to be done. Much time and hard work is saved by the use of a jack fitted with a reversible ratchet for operating the screw, as the handle of the ratchet can be turned back more easily and quickly than a bar can be removed, turned end for end, and again inserted. With a properly

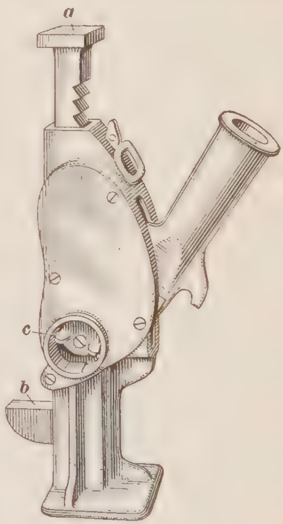


FIG. 9

formed ratchet, the jack can be operated in a very much smaller space than one operated by a detachable bar.

19. Ratchet Lifting Jack.—A typical form of ratchet lifting jack is shown in Fig. 9. Jacks of this class are used for various kinds of work. The load is carried by either the head *a* or the foot *b*, and is raised or lowered by means of a pawl and ratchet operated by a handle bar not shown. The load is raised or lowered on both the upward and downward stroke, the direction being controlled by the eccentric *c* at the side of the frame. These jacks have capacities as great as 20 tons.

20. Geared, Ratchet, Screw Lifting Jacks.—For capacities of from 20 to 70 tons, geared ratchet screw, or hydraulic, lifting jacks are usually employed, instead of jacks of the types heretofore described. The introduction of gearing enables greater leverages to be obtained, with consequent greater ease in raising or lowering the work. Fig. 10 shows a geared jack having a stationary steel base *a* over which is placed a sliding sleeve *b*, also of steel. The base is hollow and has in its top part a removable bronze nut *c*, in which the steel screw *d* turns. A steel bevel gear *e* is fitted to the upper end of the screw and upon it rests a hardened steel plate *f* on which are placed circular trains of hardened steel balls *g* held in position by steel rings *h*. A second hardened-steel plate *i* rests in turn upon the balls. The sliding sleeve *b*, which encloses the whole, supports the load and is carried by

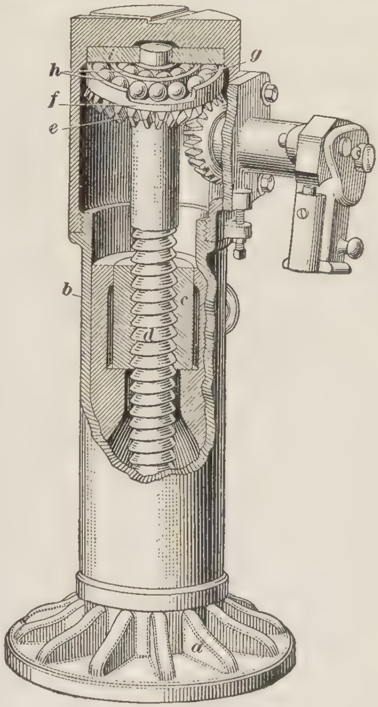


FIG. 10

this upper steel plate. The sleeve is raised and lowered by the screw which is turned by means of a reversible pawl and ratchet in a handle bar, not shown, operating through the pair of bevel gears.

21. Hydraulic Jacks.—Different kinds of hydraulic jacks are used very largely in machine shops. They are operated by

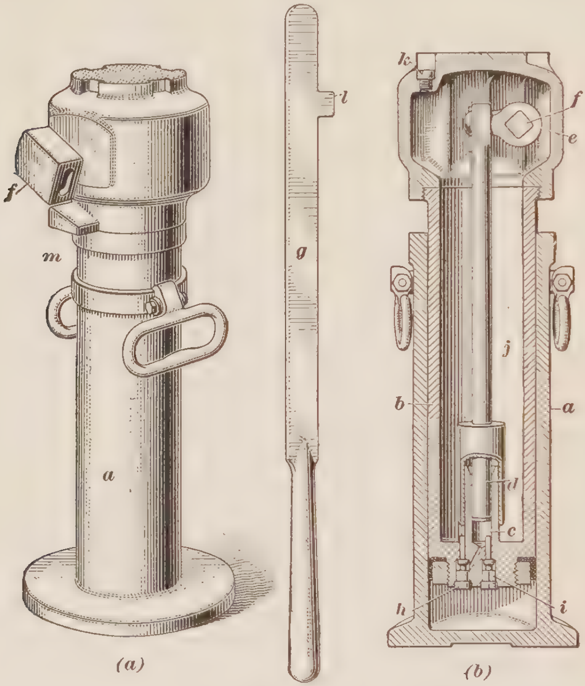


FIG. 11

pumping oil or other liquid under a piston or ram. When hydraulic jacks are subjected to cold temperatures, alcohol must be used, on account of its resistance to freezing. The lifting is done by the pressure of the fluid in the cylinder. In Fig. 11 (*a*) and (*b*) is shown a type of hydraulic jack consisting of a forged steel cylinder *a* in which is a hollow steel piston or ram *b*, free to move up or down. At the bottom of the ram and forming part of it, is a small cylinder *c*, centrally located, to

which is fitted a plunger or rod *d*, and this is in turn connected by the piece *e* to the part *f*, which receives the operating lever, or handle bar *g*. Two small valves, *h* and *i*, for suction and discharge, respectively, are located in the bottom of the ram, the suction valve *h* connecting the oil reservoir *j* in the ram with the small central cylinder *c*, the discharge valve *i* connecting the small cylinder *c* with the large outer cylinder which contains the ram. While the ram is in its lowest position, it is entirely filled with liquid, which is poured into it through a small screw plug *k*, shown at the top. In summer a mixture of 1 part grain alcohol and 4 parts distilled water by volume is used, while in winter the proportions used are 2 parts of alcohol to 3 parts of water. A small amount of sperm oil is usually added in either case.

22. To operate the jack, the lever, which has been placed in position with the lever lug *l*, Fig. 11, pointing downwards, is lifted, which raises the plunger, drawing oil from the reservoir through the suction valve and into the small central cylinder, the discharge valve remaining closed. On the downward stroke of the lever, the plunger is pushed down until the lug *l* comes in contact with the lug *m*, which forces the oil from the small central cylinder through the discharge valve into the bottom of the large outer cylinder, the suction valve remaining closed. As a result, the ram is raised an amount equal to the volume of oil displaced from the small central cylinder. It must be understood that this distance will not be equal to the travel of the piston, but will be as much less as the volume of the large outer cylinder is greater than the volume of the small one. To release the jack, the lever is reversed so that the lug on it projects upwards, thus allowing the plunger to be forced further down than is permitted in its regular stroke, which causes the plunger *d*, with its surrounding sleeve, to press on both valves, opening them and allowing the oil to return to the oil reservoir. Hydraulic jacks are built for capacities ranging from 10 to 500 tons. Their principal advantage over the geared type, in addition to their greater range of capacity, is that they are considerably lighter and are even easier to manipulate, though

requiring a little more care for their proper maintenance. They should be used only for temporary service, as there is a tendency to leak and reduce the pressure, in spite of the best of care.

FOUNDATIONS, FLOORS, AND PITS

FOUNDATIONS

23. Temporary Foundations and Temporary Erecting.—The erecting of a machine is usually understood to include both the first erecting, in the shop where it is built, and the second erecting, on its final foundation. The two differ principally in the amount of fitting and adjusting that is requisite and the facilities for handling the heavier parts. The fitting and adjusting of all the parts are done in the shop, except in cases where some of the parts are dependent on the foundation, or must be fitted to other parts that are not available in the shop. The temporary foundation on which the work is erected in the shop is either an *erecting floor* or a *floor pit*.

24. The machine should in all cases be made as complete and as perfect as possible before it leaves the shop, because the entire equipment of the shop is available and the work can be done to better advantage, whereas any fitting necessary while setting up the machine upon its final foundation must be done with a few light tools that can easily be shipped from the shop and with such devices as the workmen may be able to contrive. The ingenuity of the erecting force is often severely tested, and the most skilful workmen frequently find it impossible to produce the grade of work that could readily be performed in the shop at a much smaller cost. It is therefore a matter of economy to be certain that every part is properly fitted and the entire machine is as complete as possible before it is shipped. The erecting on the final foundation should consist simply in putting the parts together and in making the final adjustments. This is, at best, not an easy task, especially when the machine is heavy, as the facilities for handling are almost invariably temporary makeshift devices that operate slowly.

25. Permanent Foundation and Foundation-Bolt Templet.—The permanent foundation is usually built of concrete, brick, or stone. In building, due provision must be made for the foundation bolts. Sometimes these bolts are built solidly in the foundation, while at other times they are set in pipes that hold the concrete or cement while it hardens, yet permit the bolts to be adjusted or removed entirely, if necessary. In either case the bolts must be carefully set, so that when the bed of the machine is lowered in place they will meet the bolt holes. It is usually best to make a wooden templet having the exact thickness of the bed parts, with holes in the exact location of the bolt holes in the bed through which the bolts pass. By locating such a templet carefully where the machine is to stand, the bolts can be set to the proper height and in the right places; the foundation may then be built up without any danger of a misfit.

ERECTING FLOORS

26. Foundations for Erecting Floors.—The erecting in the shop is done on a floor, the construction of which depends on the weight of the machines and the condition of the earth on which the floor is built. When the earth is dry and hard, or there is a rock bottom to build upon, the foundation of the floor may be shallow; on the other hand, when the earth is wet or unstable, a deep and solid foundation should be built up. The depth of the floor foundation depends on the weight of the heaviest parts that are liable to rest upon it.

27. Kinds of Erecting Floors.—Erecting floors are made in different ways, depending on the class of work to be done; that is, whether they are intended for permanent use for one class of work, or for a wide range of work, the needs of which cannot well be anticipated and for which changes must constantly be made. The first cost, also, often becomes an important factor in determining the style of floor to be used. To meet the various requirements, the following kinds of floor are made: *earth*, *wooden plank*, *scantling*, *wooden block*, *brick*, *concrete*, and *iron plate*.

28. Earth Floors.—Where the earth is of a firm and solid character and little money can be spent for a floor, the earth may be leveled and packed down so as to make a smooth, hard floor. Sometimes the surface is formed of a layer of iron chips from 1 to 4 inches thick that are mixed with salt or other material that will cause them to rust. When they are well packed, the surface will rust into a solid, smooth mass and then form a very good floor. Besides being cheap, the earth floor can easily be dug up to form a pit to enable any machine parts that project below the floor line to be attached. On the other hand, there is always more or less loose sand upon the surface,

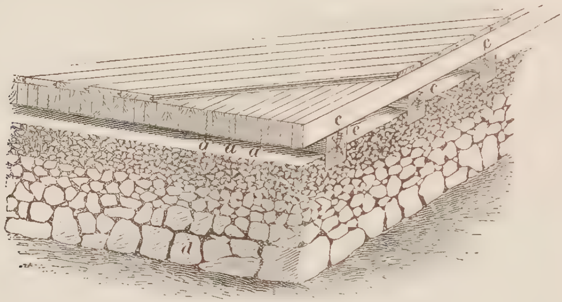


Fig. 12

which is liable to get into the working parts of a machine and cause trouble.

29. Single-Plank Floors.—A comparatively inexpensive floor consists of 3- or 4-inch yellow pine planking, laid across joists that are placed close together and are well braced or bridged sidewise. The planks are sometimes covered with a diagonal floor of $\frac{3}{4}$- to $1\frac{1}{4}$-inch pine. The spaces between the timber should be ventilated to prevent rot. Such a floor is, however, not very rigid, and hence the heaviest grades of work require something more solid.

30. Double-Plank Floors.—A more rigid floor than the plank floor previously mentioned is illustrated in Fig. 12. The floor is built up of $2'' \times 4''$ pine scantling a, with a facing of from $\frac{3}{4}$- to $1\frac{1}{4}$-inch pine boards laid diagonally, as shown. The scantlings are laid on timbers c, which are placed in a concrete

bed. These timbers are made 4 in. × 4 in., 4 in. × 6 in., or 6 in. × 6 in., depending on the duty for which they are intended. When the 4″ × 6″ timber is used, it is laid on its flat side. The thickness of the concrete depends largely on the condition of the ground. If the ground is of a firm grade, 14 inches of concrete should be sufficient for all ordinary purposes. The bed is built up by first laying a course of coarse stone, as shown at *d*, and running in some cement, then following with successive finer grades of broken stone and concrete, and finishing with a fine grade of concrete. Air spaces *e* are left between the timbers; these may be ventilated by means of openings through the walls or by holes bored through the floors. Many persons claim that this precaution should be taken with all wood floors to prevent rotting. The distance between the timbers should not be much greater than the thickness of the concrete, and it is generally thought best to limit the distance to the thickness. Excellent floors are made in this way.

31. Tar Concrete Floors.—A very good floor is made with a base of tar concrete. The ground, after leveling, is covered to a depth of about 6 inches with a layer of sand that is well rolled down. On this, 6 inches of tar concrete is placed; the concrete is composed of small broken stones covered thickly with heated tar, and, after leveling, is rolled with a heavy roller. Finally, a layer of sand mixed with considerable tar and some asphalt is applied, while hot, to a depth of about $1\frac{1}{2}$ inches and after it is rolled down, is allowed to harden. When hard, a layer of 3-inch spruce planking is placed on top of the asphalt, and $1\frac{1}{8}$-inch dressed maple flooring in strips about 4 inches wide is finally nailed crosswise to the spruce planking. The maple flooring is not tongued and grooved. No air space is left between the concrete and the flooring in this design, and the planking is laid directly upon the concrete. The tar will tend to make the foundation water-proof. The quality of lumber used and the amount of dampness in the location are important factors to be considered when deciding upon the kind of floor to use. A tar concrete floor is rather expensive, but very solid.

32. Wooden-Block Floor.—A substantial floor may be made of sawed wooden blocks, either cedar, pine, or oak, that are placed on top of a concrete bed. After tamping and leveling the ground, a layer of cinders 6 inches thick is placed on it and thoroughly rolled down with a heavy steam roller. A bed of concrete 4 inches thick is then laid on top of the cinders and leveled. The blocks may be about 6 in. $\times$ 4 in. $\times$ 4 in., and sawed from well-seasoned oak; their ends are dipped in liquid asphalt, and then laid directly on top of the concrete bed.

33. The cinders may be omitted and the concrete bed placed directly on the leveled ground, making it about 8 inches thick. The blocks are sawed to 3 in. $\times$ 12 in. $\times$ 5 in., and are placed end to end and butting together on the concrete, so that their height is 5 inches. A space of $\frac{1}{4}$ inch is left between the adjacent rows, which is filled with a mortar composed of 1 part of Portland cement to $2\frac{1}{2}$ parts of sand.

The advantages of a wooden-block floor are: (1) It is easy on the feet of the workmen. (2) The work is less liable to slip on it than on other kinds of floors. (3) Cleats, braces, etc. can be attached readily to the floor. (4) The expense of repairing is slight.

34. Brick and Concrete Floors.—Occasionally, a floor is made of brick laid in cement and placed on a solid concrete foundation. Sometimes hard paving bricks laid on edge are used instead of ordinary bricks, and cement is run in to fill the cracks. In some localities, a concrete base is covered with a thick layer of cement, which forms a very smooth and hard floor that is practically impervious to moisture.

An excellent and comparatively inexpensive floor consists of a layer of concrete from 8 to 12 inches thick laid directly on the ground, well tamped down, and leveled. A layer of sand about 1 inch thick is laid on the concrete, and a layer of concrete brick on the sand.

35. Cast-Iron Plate Floors.—Perhaps the best floor for large work is the cast-iron plate floor; but its great expense prevents its general use. In many shops, however, the expense

is warranted, since it serves as a laying-out table and a temporary machine foundation, as well as an erecting floor.

The plates are generally made stiff enough to allow them to be supported upon masonry columns without deflection. The leveling up of the plates is thus greatly facilitated when they get out of true. Sometimes they are laid in a solid bed of concrete. The plates are then supported at every point, and when the foundation is heavy, and the plates are leveled up very carefully when they are first set, the floor is quite satisfactory for some time; but if the foundation should yield slightly, or the plates should not be set quite right at first, it is impossible to set them true without taking up the whole floor and resetting it completely. Since this is a very expensive piece of work, the masonry supports with openings between them that make all parts below the floor accessible are generally preferred.

36. The top of the floor should be planed true, and should be provided with **T** slots so that the work or portable machines may be bolted to it. The slots are usually made at right angles to each other, although sometimes they are all made parallel to one side; occasionally, when much circular work is to be machined upon the floors, the slots are run in concentric circles with radial slots crossing them at regular intervals. A board flooring is sometimes laid over the unoccupied portions of the cast-iron floor plates, to preserve them the better from damage.

FLOOR PITS

37. Use of Floor Pits.—When erecting large work provision must be made for parts that extend below the floor line, or means given to reach some of the parts from beneath the machine. For this purpose, pits are made at suitable places in the floor. Cast-iron floors are often made about the edges of these pits, which are frequently lined with plates with **T** slots running down at intervals on the inside. Pits are also used in machining very large pieces, such as flywheels, that are too large to be machined on a boring mill or in a lathe.

38. Construction of Floor Pits.—The construction of pits, like the construction of erecting floors, depends very largely on the class of work done in the shop. When a definite line of manufacture is carried on, a pit suited to the needs of the work can be built; but where work of a miscellaneous character is done, it is impossible to anticipate the needs that may arise at any time, and a pit that can easily be enlarged or changed will be most suitable.

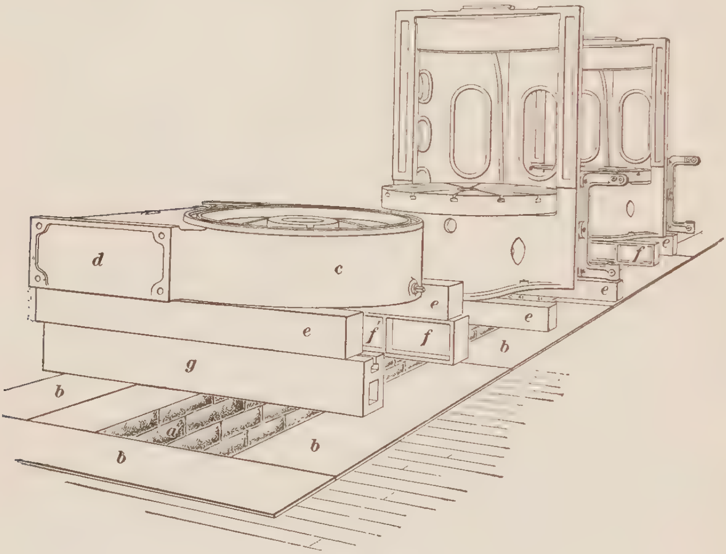


FIG. 13

39. Pit Construction for a Definite Line of Work. Fig. 13 shows a pit that is built for the purpose of erecting vertical boring mills. The sides of the pit *a* are built up of brick or stone, and iron plates *b* are placed all around the mouth of it, as shown. A convenient size of pit for this class of work is made about 4 feet deep by 4 feet wide; the length depends on the amount of work to be done.

40. The bed of the machine that is being erected is usually mounted on parallels placed across the pit. Two styles of machines are shown in Fig. 13. The machine *c* has the housings

attached to the sides of the bed at *d*, and the table is rotated on a spindle that extends below the bottom of the bed. The lower end of the spindle is carried in a step bearing that is placed in a frame which is bolted to the bottom of the bed. To fit this frame properly, there should be plenty of room beneath the bed, which is therefore placed on two parallels on each side. The two machines that are shown in the rear are self-contained. The housings and the bed are one casting, and the spindle of the table does not extend below the bed. In this case, one set of parallels is sufficient to support the machine during erection.

41. Large Parallels.—Fig. 13 illustrates several styles of large parallels. The parallels *e*, which are made of cast iron, have the general form of a box that is open at the bottom and is subdivided into several compartments by webs. These webs tie the tops and sides together and greatly stiffen the parallel. The object of making the parallels hollow is to reduce their weight. It is an advantage to have all the parallels in a set of the same height, since three or more can then be used for supporting a large piece of work having a plane surface at the bottom.

The parallels *f* have an **I** section and are strengthened at regular intervals by ribs, as the one shown at *f'*. A large parallel, as *g*, is occasionally made with a rectangular hole and a **T** slot cored in it. The **T** slot permits work to be attached to the bar by means of bolts and clamps.

42. Large Masonry Pit.—Fig. 14 shows a masonry pit intended for large and heavy work. A pit about 40 feet long, 12 feet wide, and 20 feet deep is a size well adapted for heavy work. The ends *a* and the sides *b* may be built up of stone, while the bottom *c* is made of concrete and faced with cement. The top of the pit is surrounded with cast-iron plates *d* that are planed and set level. These plates are provided with **T** slots by the use of which the work may be secured to them. The ends of the pit may be built up in steps, as shown, or may be made straight, as indicated by the dotted lines *e*.

43. When not in use, the pit is covered with a plank floor, a section of which is shown in place at *f*, Fig. 14. The floor is supported upon **I** beams, as *g*, which are set in pockets *h*, in the sides of the pit. The covering floor is made up in sections so that it can easily be removed, and each section is provided with two rings *i* to facilitate the handling. The rings are attached with staples and let into the plank, so that when not in use they lie below the surface of the floor. Where the pit is not floored

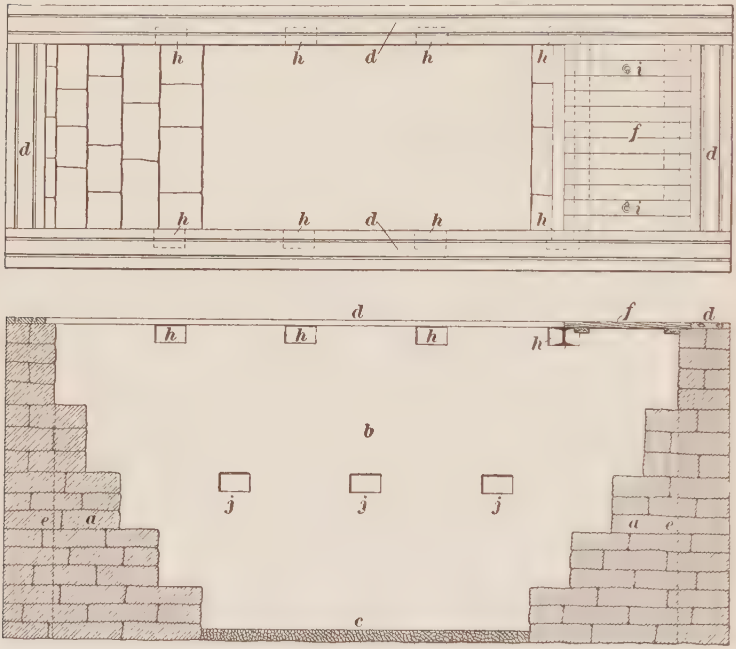


Fig. 14

over, it is advisable to place a stout removable hand railing around it to prevent workmen from falling into it. These pits may be made with one or more sets of pockets *j*, to receive the **I** beams, upon which to support sections of the floor when the full depth of the pit is not required. Such a pit may be used either for erecting or for machining large parts. This form of pit is generally used when a permanent pit is desired.

44. Wooden Pit.—Another style of pit, which has the advantage of being both cheap and easily changed or enlarged, is shown in Fig. 15. The earth is simply dug away where the pit is to go, and the floor, which rests upon heavy horizontal

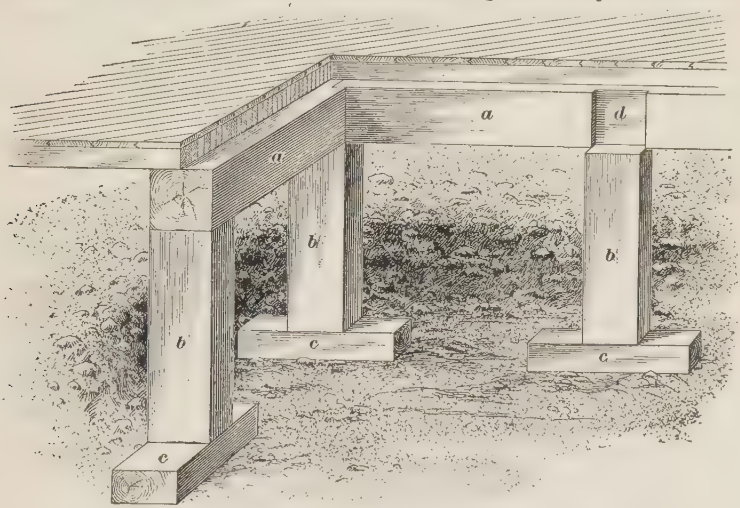


FIG. 15

timbers *a*, is supported about the outside of the pit by means of vertical timbers *b* standing on the blocks *c*. The floor, which covers the pit when it is not in use, is made in sections and is supported by timbers that are set into the pockets *d*, which are cut into the side timbers.

HOISTS AND TRUCKS

45. It frequently occurs that the heavy parts of machinery, and often the whole machine itself, must be moved, or hoisted into position. If done without proper appliances, this work involves unnecessary manual labor and becomes very expensive. Light machine parts may require no special means for hoisting, or at the most only an ordinary chain block.

The appliances used to hoist and move machinery are the *block and tackle*, the *chain* and *screw-geared blocks*, the *pneumatic* and *electric hoists*, the *derrick*, the *crane*, and the *truck*.

Whatever the type of hoisting device used, care must be taken to safeguard the operator and others. This is done by periodically testing the ropes and chains used, securing the work to the hoisting device in the correct manner, and using a device designed to lift a greater load than the one to be hoisted.

BLOCK AND TACKLE, CHAIN AND SCREW-GEARED BLOCKS

46. Principle of Block and Tackle.—The simplest form of hoisting apparatus is the block and tackle, and for some classes of work, especially in the field, it is exceedingly useful. If a sheave, or pulley, *a*, Fig. 16 (*a*), is fastened to a beam, and a rope is thrown over the sheave, a weight can be attached to one end of the rope and lifted vertically by pulling on the other end of the rope. The advantages of this device consist in changing the direction of the power exerted from an upward

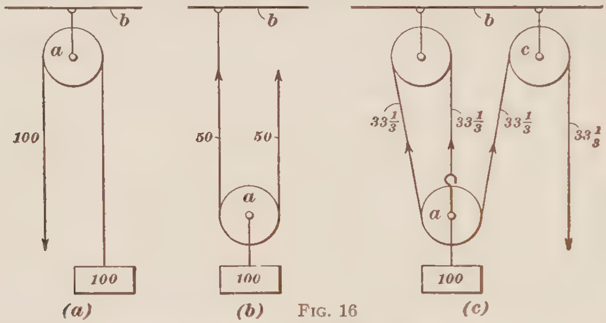


FIG. 16

lift to a downward pull, since a man can employ his strength better in this way; and further, all necessity of blocking is eliminated. Practically the same pull is required as the weight to be lifted, if friction is neglected, and for every unit of distance the weight is lifted upwards on one side of the sheave, the rope travels downwards an equal distance on the other side.

If the weight be taken as 100 pounds and the distance from the floor to the beam as 10 feet, then when the weight is on the floor the total length of rope is 20 feet; but when the weight has been lifted to the beam a distance of 10 feet, 10 feet of the rope have been hauled in, and a pull of 100 pounds has been exerted during the whole time of hauling.

47. In Fig. 16 (*b*) one end of the rope is shown attached to the beam *b*. If a man stands on the beam pulling upwards on the other end of the rope with a 100-pound weight attached to the sheave *a*, then only 50 pounds pull need be exerted by the man to lift the weight, the other 50 pounds being held by the beam. This point will be more quickly understood if in place of one end of the rope being tied to the beam, it is held by a second man, thus dividing the weight equally, each man holding 50 pounds. For every unit of distance the weight is lifted upwards, twice as much rope, as in the first case, must be hauled in. When the weight is on the floor, the total length of rope is 20 feet; but when the weight has been lifted to the beam a distance of 10 feet, all of the rope, or 20 feet has been hauled in.

48. In Fig. 16 (*c*), the same weight is shown being lifted by the aid of three sheaves and 40 feet of rope. In this case, for every unit of distance the weight is lifted, three times as much rope must be hauled in as in the case illustrated in (*a*). The total weight, 100 pounds, is supported by three ropes, each rope supporting one-third of this weight or $33\frac{1}{3}$ pounds. The pulley *c* is used so that the pull may be exerted in a downward direction. When the weight is on the floor, the total length of rope is 40 feet; but when the weight has been lifted to the beam, 30 feet of rope have been hauled in.

Rule.—*In every block and tackle, the pull required to hold any weight is equal to the weight divided by the number of ropes supporting the weight.*

When applying the rule, care must be taken not to count a free end used to change the direction of pull. For example, the left-hand rope in Fig. 16 (*a*) and the right-hand rope in (*c*) are free and should not be counted; while in (*b*) the right-hand rope is supporting the load and should be included.

49. Example of Block and Tackle.—One form of block and tackle is shown in Fig. 17. According to the method followed in practice, the sheaves, instead of being separated, as shown in Fig. 16, are placed in one block. The block and

tackle, as compared with the chain block, to be described later, are lighter and can be used to lift weights to greater heights since ropes are made in greater lengths than chains. For hoisting, the block hook *a* should be attached to some fixed support above and the tackle hook *b* should be made fast to the work. In this case a given amount of pull on the free rope *c* will cause an equal pull on the other ropes *d*, *e*, and *f*, so that, neglecting friction, a given pull on *c* can lift three times the load on the hook *b*.

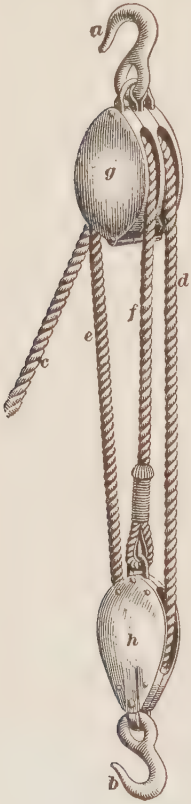


Fig. 17

The block and tackle is particularly useful in drawing to one side a weight suspended from a heavier tackle or for moving machinery supported on rollers. Judgment should be exercised in using the block and tackle to the best advantage when dragging weights horizontally; for example, if the block and tackle in Fig. 17 be used to draw a piece of machinery along the floor of a shop, the single-sheave end *h* should be attached to some stationary object, as a girder, while the double-sheave end *g* should be attached to the piece of machinery to be moved. This has the advantage of giving four ropes which pull on the greater block *g*, whereas, reversing the block and tackle reduces the number of the ropes that pull on the block *h* to three, and therefore increases the pull required on the rope *c*.

50. Differential Chain Block. Although, as already stated, the block and tackle is lighter and with it loads can be lifted through a greater distance than with the differential chain block, the latter can lift far heavier loads and is much more durable in construction. The differential chain block consists of an endless chain *a*, Fig. 18, a differential chain wheel *b*, a single-grooved pulley *c*, and the hooks *d* and *e*. The differential wheel has two chain grooves of unequal diameters.

The grooves are notched, forming two chain sprockets. As the chain is drawn over the pulley so that the latter revolves, a greater length of chain per revolution will travel over the groove with the larger diameter than over the one with the small diameter. Therefore, when the side of the loose loop *a*, which is on the large diameter, is drawn down, it will shorten the distance between the two pulleys and lengthen the loose loop. By drawing down on the other side of the chain that runs over the small diameter, the distance between the pulleys is increased. A weight hanging on the hook *e* will be raised or lowered, depending on which side of the loop is pulled.

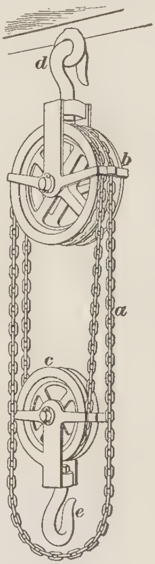
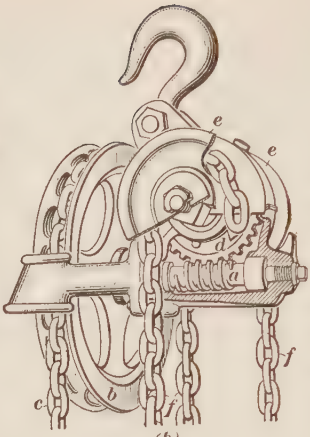


Fig. 18

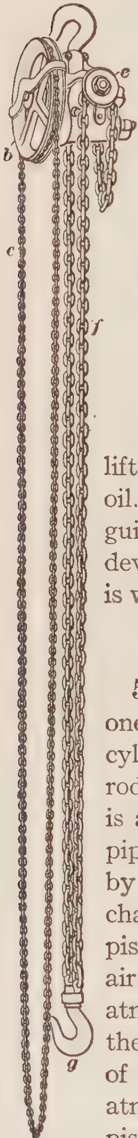
51. One great advantage of chain hoists lies in the fact that they may be stopped at any point; that is, the load will remain stationary, without fastening the chain in any way, until set in motion again by the operator. With a tackle the free end of the line must be fastened to some stationary object in order to hold the load, which is often a drawback to the use of the tackle. To offset this, is the fact that, with long usage, the iron in the chain links becomes crystallized, and is liable to break suddenly even under a moderate load. The effects of crystallization can, however, be remedied to a large extent by a thorough annealing of the chain. The chain should be removed from the blocks, coiled, and a wood or charcoal fire built around it. No blast should be applied to the fire, which should be built in the open air. After the chain has been heated to a cherry red, it should be placed in an iron box, the bottom of which has been covered with powdered charcoal. The chain should be covered with the same substance, the box closed, and the chain allowed to remain until cold. It may then be rove through the blocks again, and will be nearly as good as when new.

52. Screw-Geared Block.—A still more efficient type than the differential chain block is the screw-geared block made



(b)

in a variety of forms, one of which is shown in Fig. 19 (*a*) and (*b*). It consists of a central worm *a*, driven by a chain wheel *b* over which is thrown a hand-operated chain *c*. Meshing with this worm is a gear *d* having fastened on each side of it small chain wheels *e* over which the load chain *f* is thrown. To the ends of this chain is attached a hook *g* for lifting the load. The worm and gear run in a bath of oil. The chain wheels *e* are supplied with safety guides to prevent the load chain from slipping. This device is light in weight, requires little headroom, and is well adapted for setting machinery.



(a)

Fig. 19

PNEUMATIC AND ELECTRIC HOISTS

53. Pneumatic Hoists.—A pneumatic hoist is one operated by compressed air. It consists of a cylinder *c*, Fig. 20, in which moves a piston having a rod *r* that is supplied with an eye *e* to which the load is attached. The air pipe *p* is connected to the air-pipe line by a hose, and air is admitted to the cylinder by the three-way cock *v*, which is operated by the chain. The hoist will lift the load the length of its piston travel. To lower the piston, the compressed air in the lower end of the cylinder is exhausted to the atmosphere by way of the three-way cock, permitting the piston to return to its original position. The top of the piston is always in communication with the atmosphere and air pressure is on the lower side of the piston when lifting. The hoist described is single acting. It is shown mounted on a runway.

54. Electric Hoists.—Like the pneumatic hoists, there are many types of electric hoists available for different classes of work. They embody the same general principles, differing only in details of construction. One type of hoist is shown in Fig. 21. The hook *a*, which is connected to the part to be hoisted, is raised and lowered by electric power while the hoist and work are moved along the jib way *b* by pushing or pulling

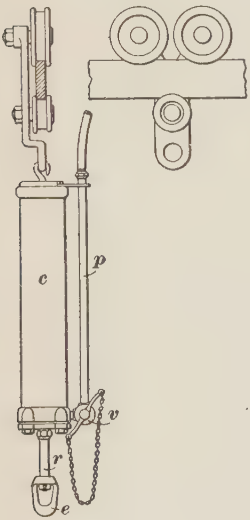


FIG. 20

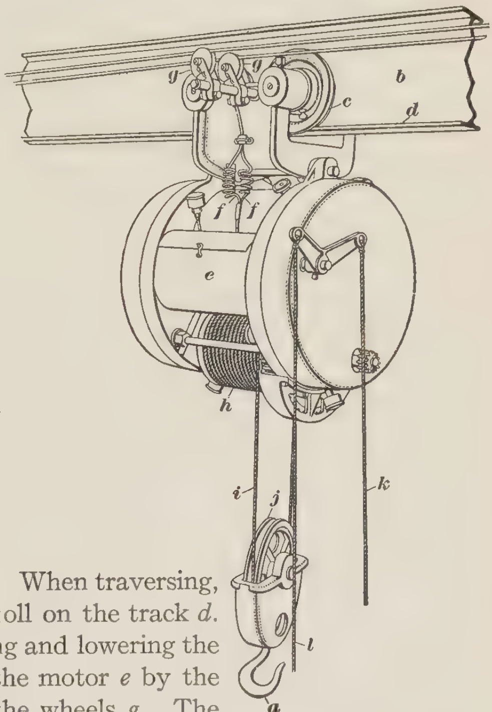


FIG. 21

on the work or hook. When traversing, the trolley pulleys *c* roll on the track *d*. The power for hoisting and lowering the work is supplied to the motor *e* by the electric wires *f* and the wheels *g*. The hook *a* is connected to the hoisting drum *h* by the rope *i* which runs over the pulley *j*. The hoisting drum is driven from the pinion of the motor by a train of gearing.

55. When the hoist is stationary, pulling the rope *k*, Fig. 21, downwards operates the controlling mechanism, causing the electricity to flow through the motor in the direction

needed to hoist the work. Pulling the rope *l* downwards then stops the hoisting, and pulling it still farther down reverses the direction of flow of the current through the motor and consequently lowers the work. Pulling the rope *k* downwards would, in this case, stop the motor, and hence the descent of the work. A brake is enclosed in the casing which, when the ropes are adjusted to the stopping positions, operates to prevent the work from descending. Some types of hoists are provided with motors which move them along the track.

Electric hoists are used for practically the same classes of service as are the pneumatic hoists; and, while at times there is little to choose between them, at other times, one type may have an advantage over the other. They are built for both stationary and traveling service.

CRANES AND TRUCKS

56. Portable, Hand-Operated Cranes.—A portable, hand-operated crane, Fig. 22, is very convenient for transporting loads up to approximately 3 tons. In the type illustrated, when the crane is stationary and the load is being raised or lowered, the handle *a*, which is connected to the crank-shaped axle of the front wheels, is thrown up. This operation lowers the body *b* of the crane on the front wheels, which then support the weight. A small **V**-shaped foot *c* is provided on both sides of the base which while clearing the floor level, is long enough to prevent the load *d* from tilting sidewise. The hoisting is done by turning the crank *e*. A ratchet wheel *f* and pawl *g* serve to hold the load at the height to which it has been raised. When the load must be lowered rapidly, the pawl may be turned over so that its back will rest on the ratchet wheel.

57. Jib Cranes.—Limited areas, and often one or two machines, are served by jib cranes, one form of which is shown in Fig. 23. Heavy jib cranes, capable of lifting 30 tons, are in use in some shops, although for heavy work the traveling crane is generally preferable. Jib cranes may be equipped with hoists that are operated either pneumatically, hydraulically, or electrically, or with a chain or screw-geared block.

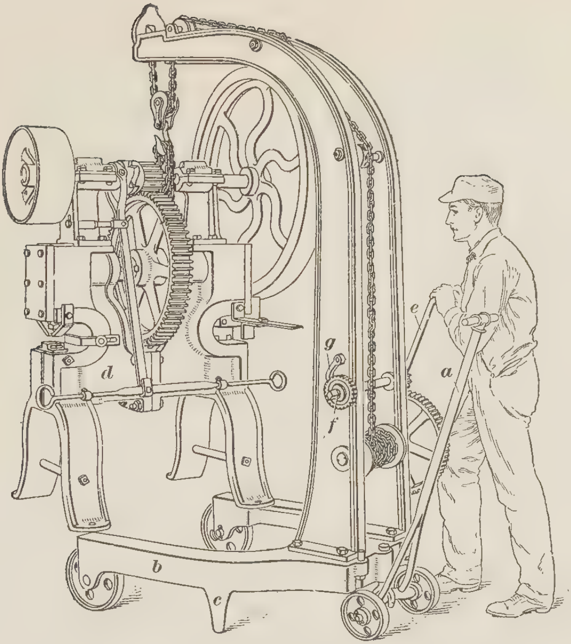


FIG. 22

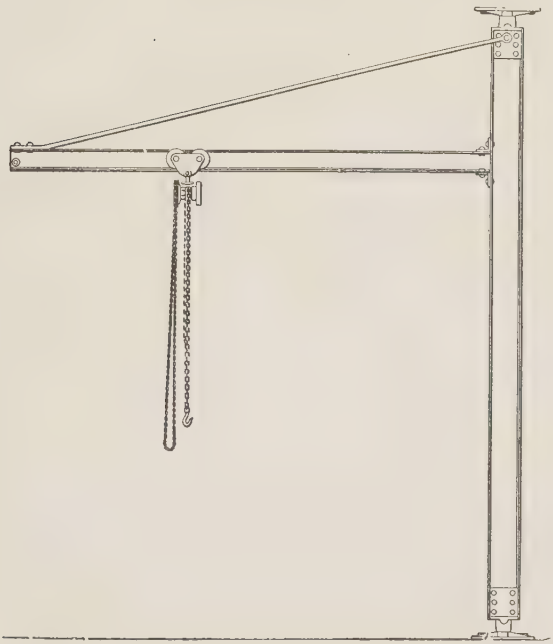


FIG. 23

58. Trolley Cranes.—The traveling hoist furnishes an extremely useful and convenient method of handling light and

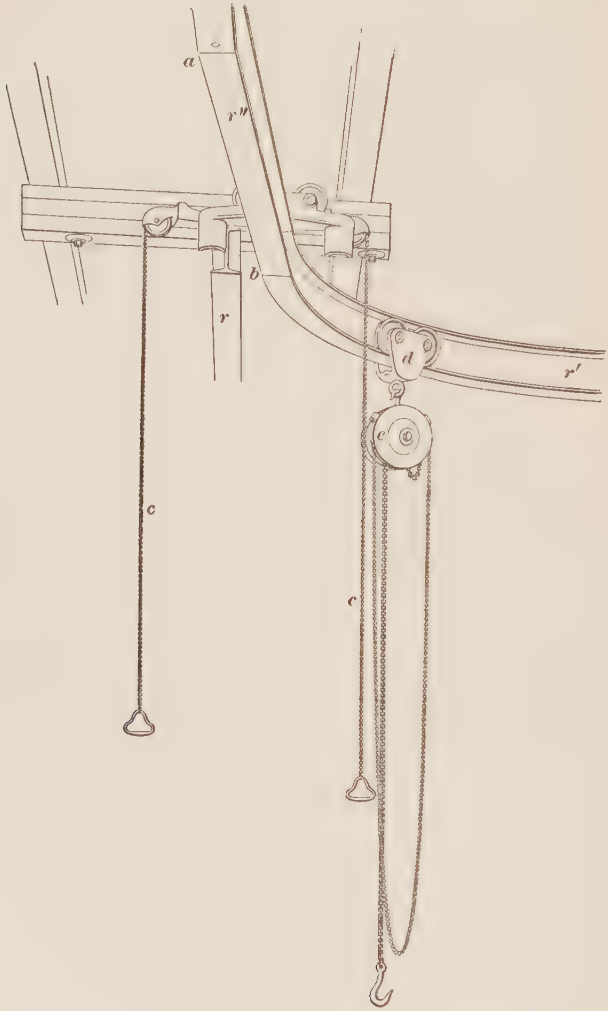


Fig. 24

medium-heavy work, and it is especially adapted to shops having low ceilings in which the traveling crane cannot be used. The runway or track used in this system of shop

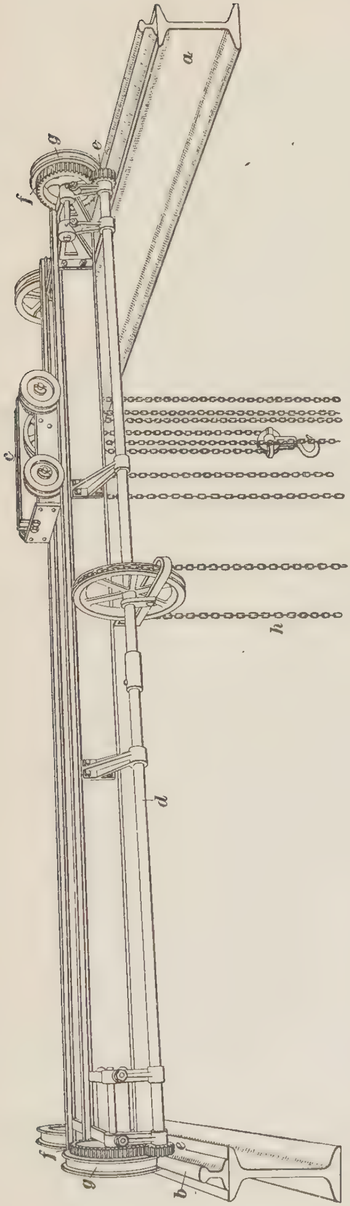


FIG. 25

transportation consists of I beams suspended from overhead, as shown in Fig. 24.

The illustration shows how the traveler *d* may be switched from the main track *r* to a side track *r′*. A section *r″* of the main track is hinged at *a*, and its free end can be swung in line with the main track or side track by pulling one of the chains *c*. The hoist *e* is attached to the traveler.

59. Kinds of Traveling Cranes.—The traveling crane furnishes the most modern and convenient means of shop transportation. Cranes of this kind are operated either by hand, by power-driven shafting, or by electric motors. The traveling crane is a bridge-like structure, that spans the floor and is supported on steel rails placed on suitable supports.

60. Hand-Operated Traveling Cranes.—Fig. 25 illustrates a hand-operated traveling crane, having a capacity of from 2 to 6 tons and built for spans of 30 feet or more. The span portion of the crane is called the bridge and the part containing the hoist, the trolley. I beams *a* carry the rails *b* on which

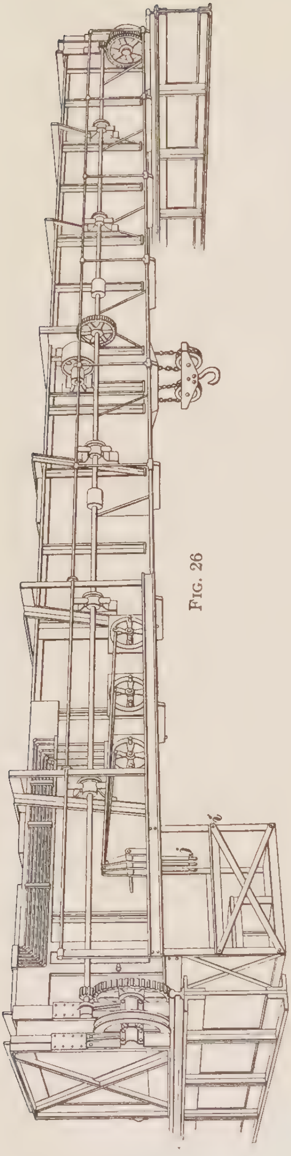


Fig. 26

the crane runs. In the case of heavy cranes, these **I** beams are replaced by built-up girders. These runways are placed as high up in the building as possible in order to get as much room under the crane as can be had. The runway extends the whole length of the floor or building and a trolley *c* running on rails can travel from one end of the bridge to the other, and hence can be brought over any point on the floor. Hand cranes like the one illustrated are operated from the floor in the following manner: A shaft *d* has a pinion *e* on each end that meshes with the gears *f*, which are keyed to the same shafts to which the wheels *g* are fastened. The shaft *d* is rotated by pulling the chain *h*, and the crane is thus made to traverse the building lengthwise. A similar mechanism runs the trolley *c* from one end of the bridge to the other. The hoisting is done from the floor.

61. Electric Traveling Cranes.—The electrically driven traveling crane may be driven by a single motor and the separate parts may be run by trains of gearing from it; but more generally it has a separate motor for each movement. Many such cranes intended for heavy work have an auxiliary hoist, to allow light work to be handled much quicker than can be done

with the main hoist. The auxiliary hoist is mounted on the trolley.

The current for operating these cranes is taken from wires

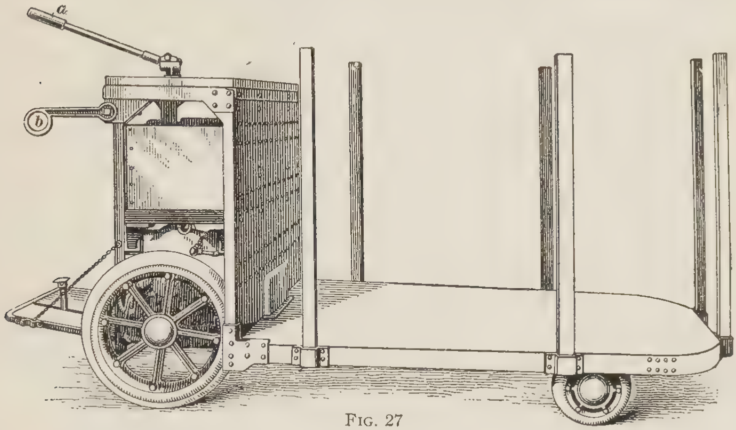


Fig. 27

located along the sides of the building close to the rails. The operator is carried in a cage *i*, Fig. 26, suspended below and to one side of the bridge, where he controls the various movements by means of levers, switches, or other devices shown at *j*.

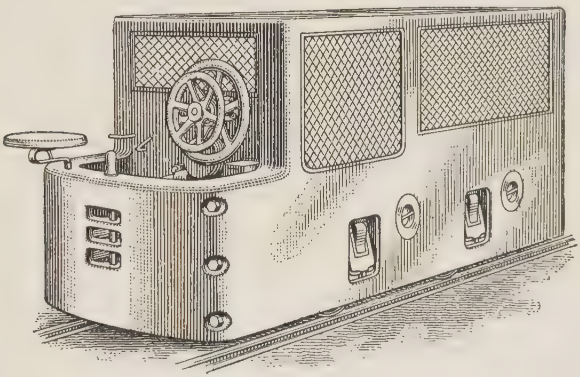


Fig. 28

Electric traveling cranes are built for spans as great as 75 feet. For heavy work, they are both economical and quick in operation.

62. Trucks.—*Hand trucks* are the most common conveyance for small loads. They are also the most inefficient vehicle used, in their method of employing human labor. Electric- and gasoline-operated trucks are consequently gradually replacing them.

Electric trucks may be either self-contained and operated by storage batteries mounted directly on them, as in Fig. 27, or they may be driven from a central station through the medium of an overhead trolley. The former are employed both for indoor and outdoor service; the latter largely for outdoor use. The truck shown in Fig. 27 is steered by the lever *a*, and the speed of the truck is controlled by the lever *b*. *Gasoline-operated trucks*, Fig. 28, are, like the battery-operated trucks, self-contained; but unlike them, they are largely confined to fixed routes, in which respect they resemble the trolley-driven electric trucks. They are used principally for outdoor transportation.

DERRICKS

63. A common form of **derrick** is shown in Fig. 29. It consists of a mast *a*, the lower end of which is set into a base *b* that is secured to the timber framing *c* shown in the illustration. The upper end of the mast carries the derrick head *d*, to which the guy ropes *e*, *f*, *g*, and *h* are fastened. These guy ropes are fastened to stakes driven into the ground, or to any other immovable objects that are conveniently located, and serve to steady the mast. The mast has pivots at both ends that enter sockets in the base and in the derrick head, and allow the mast to be rotated. The boom *i* is hinged to the mast at *k*, and can be raised or lowered by the tackle *l*. The tackle *m* is used for hoisting weights.

64. When the upper end of the mast and boom are tied together by a *jib*, or horizontal member, the whole device is called a *crane*. A crane is usually fitted with a traveling carriage on the jib.

65. Erecting Gin Pole.—A **gin pole** is a vertical pole used for hoisting. When erecting a tall derrick, a gin pole is first put up to assist in raising the mast; but if the derrick is low, its

boom may be used for this purpose. Before erecting the gin pole, a pulley is secured to its top and a rope passed over it. One method of erecting the gin pole is to slip an iron bar *a* through the hole in the lower end and secure it to suitable stakes *c*, as shown in Fig. 30. The free end of the gin pole

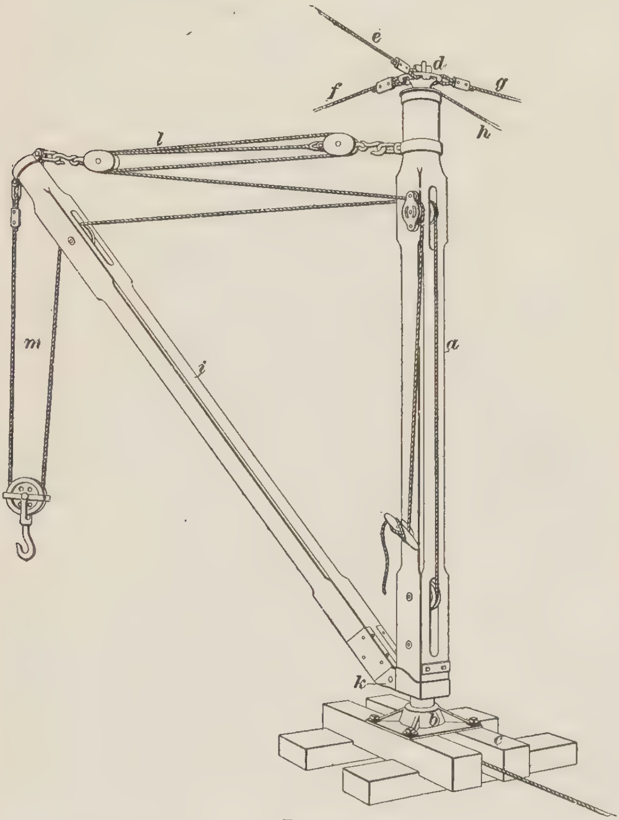


FIG. 29

is then lifted from the ground and placed on the **X**-shaped brace *e*. The guys *f*, *g*, *h*, and *i* are then attached to the upper end *d* and are laid out on the ground ready for use. The men now raise the gin pole *b* by means of pike poles and advance the support *e* toward the lower end. When the free end has been raised some distance from the ground, the ropes *f* and *i*

may be pulled, thus helping to raise the gin pole to a vertical position; meanwhile, the men who attend to the guys *g* and *h* must see that the gin pole does not shift from the desired position. Usually only one man is required for each end of the guys *g* and *h*, since he can wind the rope about a stake, and then easily prevent the gin pole from moving too far. When the gin pole has been raised to the vertical position, the guys *f*, *g*, *h*, and *i* are secured to the anchor stakes as shown in Fig. 31. Guys used for a gin pole are generally made of manila or hemp rope.

66. Erecting Mast of Derrick.—After the gin pole has been raised into an upright position and the guys have been

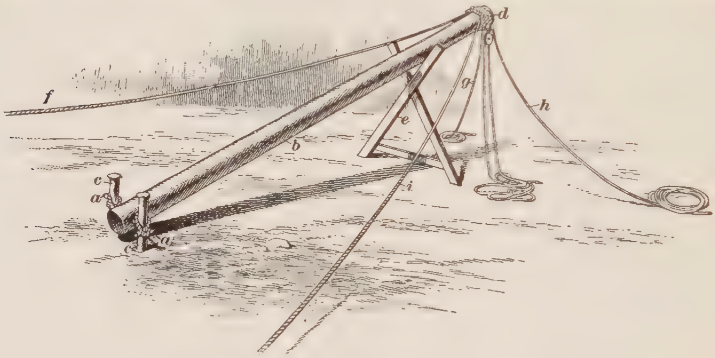


FIG. 30

fastened, it may be used to lift the mast, as is shown in Fig. 31, in which *a* represents the gin pole, the lower end of which is lashed to the stakes *c*. The derrick head *g* should be placed in position, the guys attached and the hoisting rope passed over the head sheave before the mast is raised. The base for the derrick having been located and fastened to the timbers *b*, the mast *d* is hoisted into position by means of a rope fastened a little above its center and passed over the pulley *e* on the end of the gin pole. The other end of this rope *f* may be handled by hand if the mast is not too heavy, or by a suitably located winch, or crab, if the mast is of considerable weight. The lower end of the mast is now lowered into the base, after which the guys attached to the head *g* are tightened and

fastened in position. The permanent guys for the mast are usually made of wire rope.

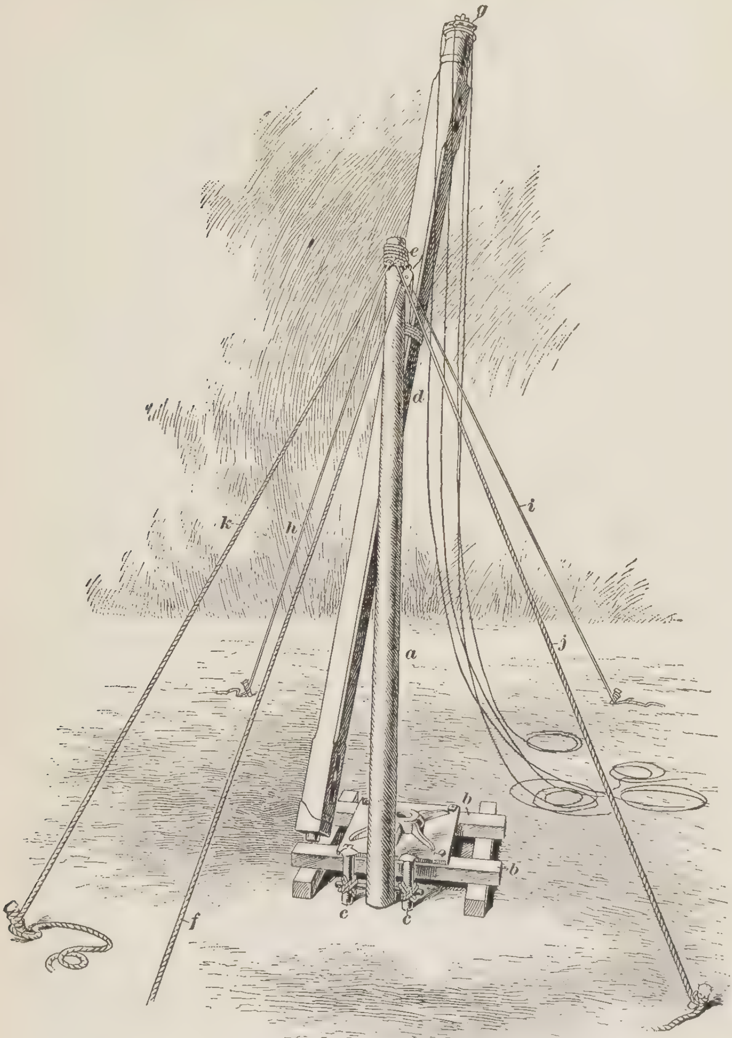


Fig. 31

67. Placing Boom of Derrick.—After the mast has been properly guyed and the gin pole has been taken down, the

hoisting rope is hitched around the boom, and it is raised until the bottom end can be swung into the knee *k*, Fig. 29, where it is secured by a pin. The ropes are then all reeved through their proper pulleys and the derrick is ready for work.

Large derricks are generally erected by the aid of a separate gin pole, as just described. In the case of a very large derrick it is sometimes necessary to erect a gin pole of a height such that the men can handle it, and use it for setting the boom on end, which is then used as a gin pole for lifting the mast. Two separate sticks of timber are sometimes used as gin poles, a short one, less than one-half the height of the mast, being employed to set a gin pole about two-thirds the height of the mast; this second gin pole is then employed for setting both the mast and the boom. Derricks so large as to require two gin poles for their erection are rarely used except on permanent work.

68. Erecting Small Derrick.—With small derricks, a gin pole is seldom used for raising the mast, as the boom is generally light enough to be erected as a gin pole, and is then employed for raising the mast. After the mast has been raised and securely guyed, the mast itself is used for swinging into position the boom, which up to this time has served as a gin pole.

69. Dismantling Derrick.—When the work has been finished and it becomes necessary to dismantle the derrick, the boom is hoisted up to the mast, and is detached from the knee. Stakes are then driven into the ground and the lower end of the boom is lashed to them; the boom is then used as a gin pole for lowering the mast. The boom itself is lowered afterwards by paying out two of its temporary guys until it can be caught on a support similar to that shown at *e*, Fig. 30.

If the boom is too large to be handled in this way, a smaller gin pole is erected alongside to take the large one down, and then lowered by the guys and **X** brace.

ROPES

70. Materials Used for Ropes.—Until comparatively recent years, all ropes were made of vegetable fiber teased out and spun into suitable form either by hand or machinery; but since the introduction of iron, and particularly of mild steel, into the rope-manufacturing industry, steel rope is rapidly superseding all other rope for certain classes of work. For many purposes, however, fiber ropes are still used and can never be replaced by steel ones; they are made, for the most part, either of hemp, manila, or coir, which is cocoanut-husk fiber. First, the fibers are spun into yarns, then the yarns into strands, and, finally, the strands into rope.

(a) Fig. 32 *(b)*

71. Slings.—Loops of rope or chain used for attaching weights to the hook of a tackle or for fastening a tackle block to some support, are known as **slings.** That a sling may best serve its purpose, one of several methods of fastening it to the block must be chosen, the choice depending to some extent on the weight of the load to be lifted. For instance, the resistance of the sling is least if used single, as shown in Fig. 32 (*a*); but its greatest possible strength may be obtained by use of a half-hitch; that is, by looping it over the hook as shown in Fig. 32 (*b*), thus increasing the surface of the sling in contact with the hook of the tackle block. The sling may be applied to the piece of work to be moved either singly, as in Fig. 32 (*a*), or doubled, as in (*b*), the latter method being preferable owing to the absence of any danger from slipping of the sling. If the sling is fastened by doubling over, a noose is formed and the sling is thus tightened on the work when the free end is pulled.

72. Lashings.—Where headroom is limited, the tackle may be attached to the work by means of a lashing, that is,

a piece of rope sufficiently long to admit of its being passed several times around the piece to be moved. Work is fastened to the tackle by first bringing the back of the hook of the tackle block in contact with the piece to be hoisted, as shown in Fig. 33, and then passing several turns of the line around the work and over the hook, the ends of the line being fastened by a knot. A small rope may be used for lashing, the necessary strength being obtained by increasing the number of turns.

73. Inspection of Ropes, Slings, and Lashings. From repeated use and occasional abuse, the strength of ropes, slings, and lashings will be impaired; to prevent any accident that might occur from this loss of strength, it is necessary to know how to detect a weakened rope. The outside must first be inspected carefully, running over the lines from end to end, and noting if any of the strands, or yarns composing the strands, are damaged. If nothing wrong is discovered about the outside of the rope, the inside should be inspected, as a rope will often be perfectly sound on the outside, but utterly bad inside. The inside may be inspected by taking the rope in both hands and untwisting it sufficiently to expose the inner surfaces that have been chafing against one another. Then, if the life or utility of the line has been impaired by long use, a considerable number of broken fibers will be found; if in a bad state, they may have been reduced to powder. If broken fibers are discovered, the use of the rope should be confined to loads not heavier than half the load it formerly could stand; if a considerable quantity of powder is found, the line should be condemned at once as unfit for use.

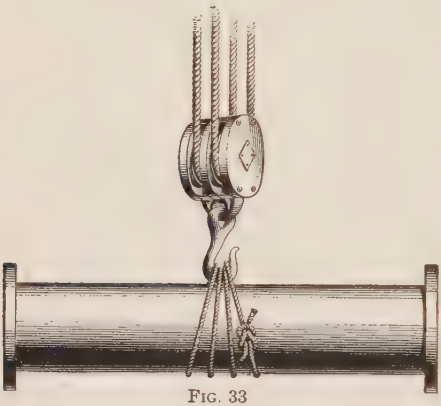


FIG. 33

Slings and lashings, as a general rule, are ruined by external chafing received when moving rough castings, etc., and hence their safety can be determined from their external appearance. Ropes or lines, on the other hand, when used for tackle blocks, receive the greatest wear on the inside, owing to the chafing and grinding of the strands when passing over small pulleys under heavy strains.

74. Splicing.—The operation of so joining two pieces of rope as to obtain one continuous piece with no appreciable increase of diameter at the splice, is known as splicing. The principal splices are the *short splice*, the *long splice*, and the *eye splice*.

FIG. 34

The principle of all splicing consists of joining, or *marrying*, the strands, thinning them out and tapering them so that the diameter at the splice is the same or only slightly greater than that of the rope itself. In the long splice, no increase in diameter is allowed. The methods of splicing described and illustrated in this Section apply only to three-strand fiber ropes.

75. Splicing Tools.—The only tools necessary for making a splice are a **marlinspike,** shown in Fig. 34, and a knife. The former is made of either iron or hard wood, is from 12 to 14 inches long, and about 1 inch in diameter at the thick end, the other end being sharpened to a blunt point about as shown in the figure. When splicing, the point of the marlinspike is pushed through the rope, between the strands that are to be separated, the thick end is placed against the body of the operator, and, using both hands, the rope is untwisted so as to render the work of opening the strands comparatively easy. The rope

is held by the left hand, the joint being made by manipulating the end of the rope held in the right hand.

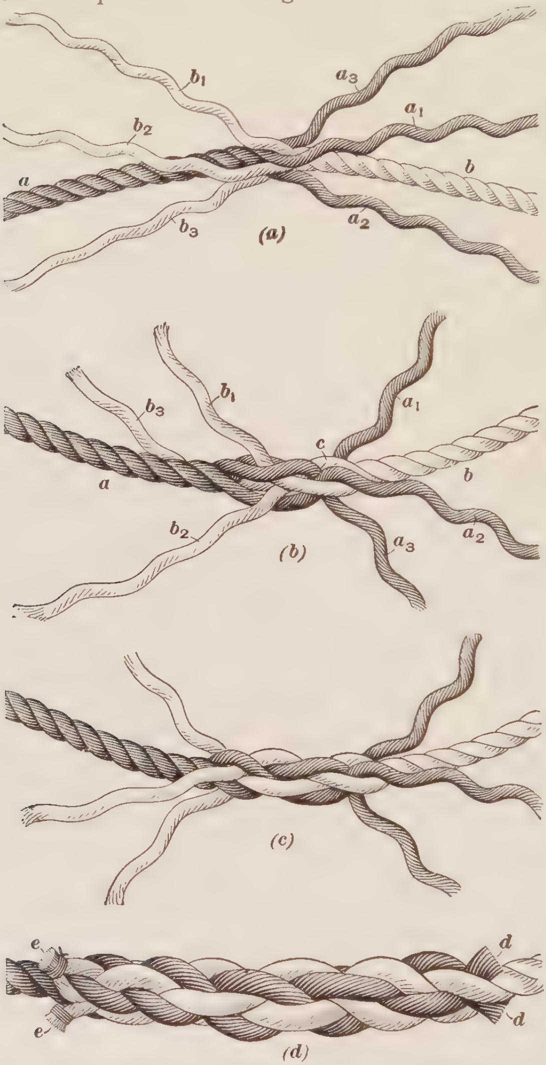


FIG. 35

76. Making Short Splice.—In making a short splice, the strands at the end of each rope are first unlaid, that is, the

strands are untwisted—a distance, for a 1-inch rope, of about 16 inches. Ropes of other diameters are unlaid a proportionate distance. A few inches too much unlay is better than too little, as the ends must be cut off anyway. The ends of the ropes a and b, Fig. 35 (a), are now married—that is, the strands a_1, a_2, and a_3 of the one rope are placed between the strands b_1, b_2, and b_3 of the other rope. The strands b_1, b_2, and b_3, and the rope a are now held in the left hand; if the ropes are too large to be held in this way they may be fastened together with twine. One of the strands, say a_1, is then pushed under the second strand in front of it, shown at c, Fig. 35 (b), an opening having previously been made either with the thumb or a marlinspike as illustrated in Fig. 34. This operation is known as *tucking*. Similarly, the strands a_2 and a_3 are tucked under the second strand in front of each. The splice now appears as shown in (b). The strands b_1, b_2, and b_3 are now tucked under the second strand in front of each, and the splice appears as shown in (c). To secure strength, more tucks are made, and, after subjecting the rope to a good stout pull, the ends of the strands are either cut off as shown at d in (d) or are whipped as shown at e. To whip the strands, one-half of each strand is wrapped, or bound, with twine to one-half of the adjoining strand. Whipping prevents the strands from creeping through when the splice is taxed to the full capacity of the rope.

77. Making Long Splice.—In the short splice, the diameter at the joint is greater than that of the rope, hence it is not a suitable splice where the rope is to be used in tackles and pulley blocks, or in other places that will admit nothing larger than the rope itself. In such cases the long splice is used. When properly made, the untrained eye can hardly distinguish this splice from the rest of the rope. To make the long splice, the ends are unlaid as before, but about three times as far, and married as shown in Fig. 35 (a). The strands a_2 and b_2, Fig. 35 (a), are then laid together as shown at f, Fig. 36. The strand b_1, Fig. 35 (a), is now unlaid gradually and in the groove thus made the strand a_1 is laid. Care should

be taken to give all the strands the proper twist, so that they will fall gracefully into the grooves. The original twist in the strands is thus retained for subsequent operations. The strands a_1 and b_1 are laid together at g, Fig. 36, as was done at f. The strand a_3, Fig. 35 (a), is next unlaid gradually and in the groove thus made the strand b_3 is laid. These strands are now laid together at h, Fig. 36, as was done at f, and the ends of all the strands are cut off to a length about as shown in the figure.

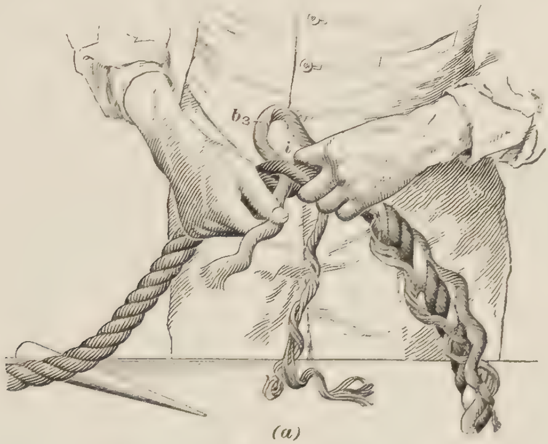
78. The strands a_3 and b_3, Fig. 36, are now relieved of about one-third of their yarns—that is, the portions a'_3 and b'_3 are cut

FIG. 36

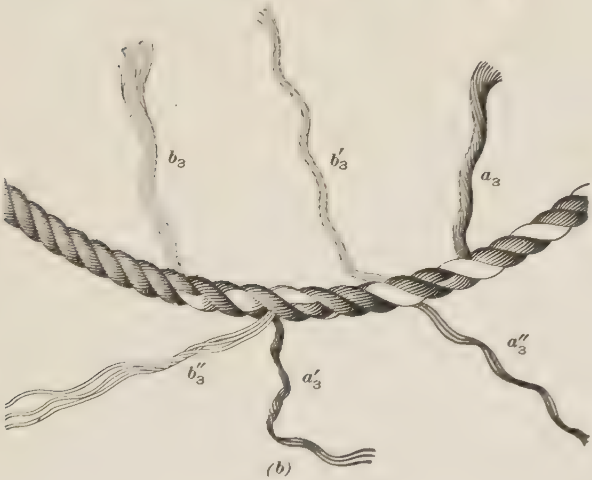
off close to the rope. With the remaining parts of a_3 and b_3, an *overhand knot* is cast, like that shown at g, Fig. 36. An opening having been made with the thumb or marlinspike as shown in Fig. 34, the strand b_3 is tucked under the strand immediately in front of it, i, and pulled taut as shown in Fig. 37 (a). Similarly, the strand a_3 is tucked under the strand immediately in front of it and pulled taut.

The strands a_3 and b_3 are now relieved of about one-third of the yarns remaining, the parts a_3'' and b_3'', Fig. 37 (b), being removed; and, an opening having been made either with the thumb or marlinspike, the strand b_3 is tucked under the

second strand in front of it, j, Fig. 36, and pulled taut. Similarly, the strand a_3 is tucked under the second strand in front of it and pulled taut. Further tucks may be taken, if



(a)



(b)

FIG. 37

desired. The splice is next finished at f and g, Fig. 36, in the same manner as at h. The rope is now given a good stout pull and the ends of the strands are cut off. The finished splice appears as shown in Fig. 38.

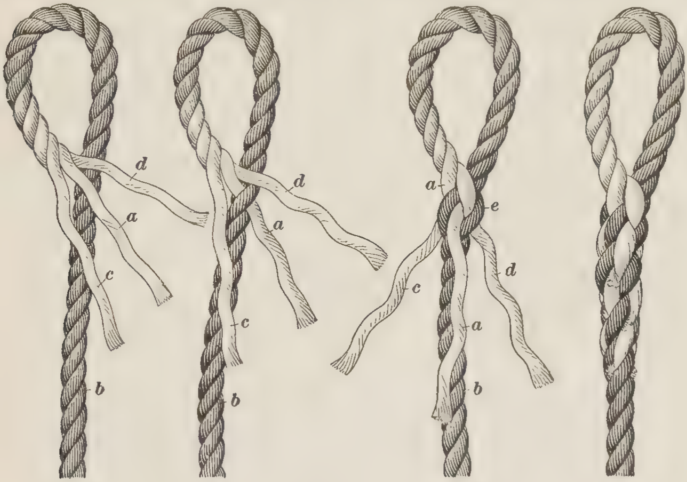
Sometimes the overhand knot is made without first thinning the strands and then split, and the half strand put through as described; but the surface of the splice is never as smooth as by the other method, which, for strength and neatness, is generally preferred.

79. Making Eye Splice.—Another splice, and one that is as common and useful as the two already described, is the eye splice illustrated in Fig. 39. To begin this splice, the end of the rope is unlaid about as far as for the short splice, and bent into the required size of eye, as shown at (*a*). The end of the middle strand *a* is then tucked under one of the strands of the

FIG. 38

standing part *b*, the necessary opening having previously been made with the marlinspike, and pulled tight, getting what is shown at (*b*). The strand *c* is now pushed, from behind, under the strand on the standing part *b* next above that under which the strand *a* was passed, so that it will come out where *a* went in, as shown in (*c*). The third strand *d* is then passed under the remaining free strand *c* in the standing part *b*, next to the one under which *a* was passed. The strands are now pulled taut, and from each one-third of the yarns are cut out and each strand is again tucked under the second strand in front of it as shown in (*d*). After this operation is repeated, the rope is given a good stretching and the ends are cut off.

80. Knots, Bends, and Hitches.—In Fig. 40 are illustrated a few methods of making knots and bends, applying slings and ropes to hooks, barrels, etc., and a few other knots and hitches useful to those engaged in workshops. Should a rope be too long for some temporary purpose, it may be arranged with a *bight* as shown in (*a*); if several bights are laid up to shorten the rope to the required length, the standing part is passed through and over the ends of all, and the rope is pulled tight. In (*c*) is shown how a sling or strap should be applied to a hook when the rope spreads away to its load; this



(*a*) (*b*) FIG. 39 (*c*) (*d*)

hitch will prevent the sling from slipping in the hook, in case the load should come in contact with some obstruction while being hoisted. In (*b*) and (*d*) is shown how a smaller rope should be secured to one of greater diameter.

81. The **Blackwall hitch** is illustrated in Fig. 40 (*e*); except for very light loads, this should be made, with a **double hitch**—that is, with the end twice around the hook—as in the figure. Experience has proved that this is the safest way, since with only one turn, the end is liable to creep when subjected to a heavy pull, expecially in damp weather, when the moisture absorbed by the rope acts as a lubricant. When a rope is too

long to conveniently secure its ends to a tackle, a bight of it twisted as in (*f*) is very handy and useful. To make this

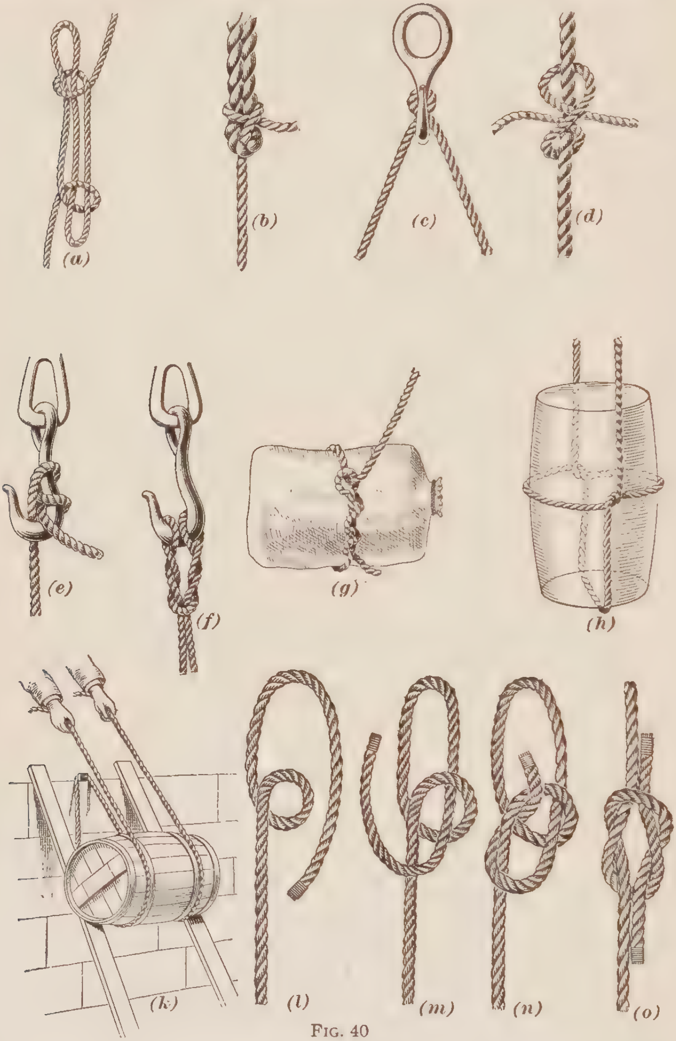


Fig. 40

hitch, commonly called a **cat's paw,** take hold of the rope with both hands at places about 2 feet apart, and twist it two or three times each way; then apply the ends of the loops thus

made to the hook. The twisting prevents the rope from becoming jammed, and the hitch is very easily undone. In (*g*) is illustrated a **timber hitch,** so simple that explanations are unnecessary. In (*h*) is shown how to apply a rope to a barrel or similar vessel when it must be hoisted in a vertical position. In (*k*) is shown what is known as a **parbuckle;** this hitch is used for raising a heavy cask or similar load with a single length of rope.

82. A very useful knot, the making of which should be understood by every mechanic, is shown in Fig. 40 (*l*), (*m*), and (*n*); by seamen, this knot is known as the **bowline knot.** When making this knot, a bight, turn, or loop, as shown in (*l*) is first made, after which the end is passed through the bight as shown in (*m*). The knot is completed by passing the end around the standing part and through the bight again. The finished knot is shown in (*n*). The **square knot,** shown in (*o*), is probably the most common knot used to tie two ropes together.

ERECTING
(PART 2)

FITTING AND INSPECTION OF WORK

FITTING OF PARTS

1. Classification of Fits.—Two pieces of work may be tightly joined together either by pressing or driving one of them into or over the other; or one part may be expanded by heating, placed over the other, and allowed to cool, when it then tends to return to its original size; and, if the proper allowance has been made, a very rigid and durable joint is the result. Fits made by driving the pieces together are called *drive fits;* those in which the pieces are pressed together *press fits;* and those which are effected by heating, *shrink fits.*

In addition to the fits enumerated, there are two other kinds, known as *sliding* and *running fits;* but in these, as their names imply, the parts fit loosely into each other, the bore being larger than the shaft or the equivalent, and no pressure being required to put the parts together. The former is sometimes spoken of as a *free fit,* and the latter, which is the easier or looser of the two, as a *bearing fit.*

2. Press, drive, or shrink fits, when properly made, produce excellent joints; but if a shop is equipped with presses and the character of the work permits it, the press fit is to be preferred, since it is the most easily as well as the most accurately made and the pressure applied can at all stages be observed by means of a gauge on the press. When no press is available, the parts

may be driven together with hammers or rams. Sometimes, however, neither a press nor a ram can be readily applied,

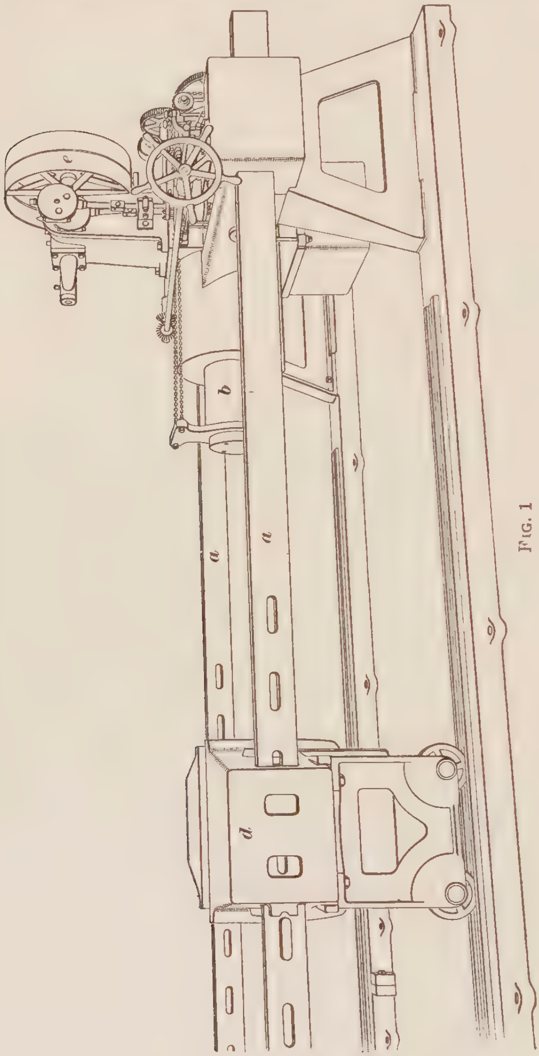


FIG. 1

and the shrink fit may then be used to the best advantage, as in making the joints of flywheels, shrinking locomotive tires on

wheel centers, etc. In these instances, a link, bolt, or ring, as the case may be, is made a little shorter or smaller than the place in which it is to be located and is then heated until it goes freely into its position, after which it is allowed to cool, thus drawing the parts tightly together.

3. Stationary Hydraulic Press.—Fig. 1 shows a hydraulic press that is used for such work as pressing the cranks on engine crank-shafts and general pressing on or off in making press fits. It is made of from 200- to 400-ton capacity. The tie-bars *a* are placed on either side, so that the work can be lowered into, and lifted out of, the press with a crane. For use in railway shops, the tie-bars are placed one below the floor and the other overhead, thus enabling the rolling in and out of the car wheels or locomotive wheels. The same tie-rods, or similar ones, may be used with hydraulic jacks for portable-press work.

4. This machine will take 10 feet between the tie-bars and 25 feet between the ram and sliding head. The ram *b*, Fig. 1, is 14 inches in diameter, has a stroke of 4 feet, and is provided with a counterweight so that it returns automatically when the release valve is opened. It is supplied with a safety valve that can be set to open at a desired pressure, which makes it impossible to push more than a specified amount. The valve is locked in a box cast on the cylinder. The pressure gauge is graduated for tons pressure on the ram and pounds per square inch of its area. The sliding head *d* moves on a track, and is held in position by steel keys. The force pump is driven by a belt placed on the pulley *e*, and takes its water supply from a tank underneath, to which the water is returned.

5. Portable Hydraulic Press.—Fig. 2 shows a portable hydraulic press that will exert 100 tons pressure or more, consisting of a cylinder *a* and ram *b* with side bars *c* and cross-ties *d*, hand pump *e*, reservoir *f*, and gauge *g*. The side bars are held between the parallel lugs *h* on each side of the cylinder and are provided with slots suitably spaced into which keys *i* may be inserted. A pair of keys are inserted in corresponding slots at both ends of each side bar, the cross-ties bearing against

one pair of keys while the cylinder bears against the other pair. The pieces of work *j* and *k*, which are to be forced together, are placed between the cross-ties and the ram and maintained in their proper positions, if necessary, by being blocked up from the floor or supported by a crane. Pressure is exerted by means of the hand pump, operated by the lever *l*, which draws the fluid from the reservoir and forces it into the cylinder, driving the ram forward against the work. The opening of a valve relieves the pressure and allows the fluid to return to the reservoir. A second lever *m* enables the ram to be ratcheted back to its starting position.

6. Straight Press Fits.—Press fits may be classified as *straight* and *taper*. In a straight press fit, the internal piece,

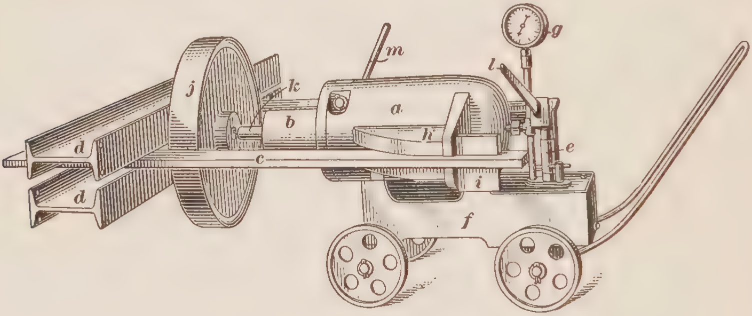


FIG. 2

as a shaft, must be only enough larger than the hole to insure the development of sufficient friction between the two pieces to hold it there securely when pressed home. The amount of friction is judged by the total pressure in tons on the piston of the press that is required to force the pieces together. The allowance that must be made—that is, the difference in the diameter of the two pieces required to insure a pressing together at a given pressure—cannot be accurately calculated, as the pressure depends on a number of variable factors whose values can only be approximately determined. Some of these factors are the length of the hole compared with its diameter, the relative smoothness and exactness of the surfaces that are to be joined, the amount of metal and the manner of its distribution

around the hole in the external piece, and the character of the material. Experience, judgment, and experiment must therefore be largely relied on in work of this kind. In making a press fit the two parts should, as a rule, be lubricated with a heavy oil or grease, to prevent cutting, which might destroy the entire fit on both pieces. White lead is often used instead of oil.

7. Influence of Temperature on Fits.—If standard 1-inch cylindrical plug-and-ring gauges are tried together when they are at equal temperatures, the plug can only be pushed through the ring by exerting considerable force, since the size of each gauge is so near that of the other as to make the fit almost perfect. If the ring is held in the hand a few minutes, it will become larger and the plug can be easily pushed through it; if the plug is dipped in cold water and the ring warmed, the difference in size is so increased that the plug will fall through. From this experiment it is seen that metals expand when heated and contract when cooled.

8. Allowances for Different Fits.—The amounts allowed for various kinds of fits are treated in a general way in the following articles and table. Running fits for work less than 1 inch in diameter may be made by making the internal piece .0015 to .002 inch under the size of the hole, while a $2\frac{1}{2}$-inch shaft may be as much as .005 under size. Drive fits are spoken of as tight and easy. The values given in Table I are for tight fits; the allowance for easy drive fits may be taken as one-half of that given.

9. In Table I, the allowances given for different fits represent the average allowances made in several good shops; but the conditions prevailing in the work being done govern the amount of force necessary to force two pieces together. For this reason the pressure necessary to push the parts together is seldom given in a table of allowances. For force fits, the shaft must be made larger than the bore by the amount given, and for sliding and running fits, smaller by the amount given.

10. The pressure required to force the work home varies with the allowance made, the character of the surfaces, the material, and the degree of hardness. The following examples

taken from practice give a general idea of the relation between pressure and fit allowances:

Two crankpins were required to go in holes 5 in. × 8 in. at 50 tons pressure. The pins were turned .003 inch larger than the diameter of the holes and went home at a pressure of 45 and 48 tons, respectively.

A car wheel with a bore $4\frac{7}{8}$ inches in diameter and 7 inches long required a pressure of 30 tons to force it over the axle, an allowance of .007 inch having been made.

11. Taper Press Fits.—For some purposes, the taper fit is preferable to the straight fit. In a taper fit, the hole is bored

TABLE I

ALLOWANCES FOR DIFFERENT FITS

Diameter Inches	+Allowance on Shaft Inches			−Allowance on Shaft Inches	
	Press Fit	Drive Fit	Shrink Fit	Sliding Fit	Running Fit
1	.001	.00075		.001	.002 to .004
2	.002	.00075		.002	.004 to .006
3	.002	.00125	.00225	.003	.006 to .010
4	.002	.00125	.00300	.004	.007 to .011
5	.003		.00375	.005	.008 to .012
6	.003		.00450	.006	.009 to .015
7	.003		.00525	.007	.011 to .017
8	.004		.00600	.008	.012 to .018

tapering, frequently $\frac{1}{16}$ inch per foot, and the internal piece is turned to the same taper as the hole, or in the practice of some, an increase of .001 of an inch to the inch of length is allowed; that is, if the large end of a hole 20 inches long measures 15 inches, the large end of the internal piece would be made 15.020 inches in diameter. If the hole is very long, the amount allowed may be made less than .001 inch per inch of length.

12. Taper fits are sometimes made in the following manner: The hole in a hub, wheel, or crank is first bored with a taper of,

say, $\frac{1}{16}$ inch per foot. A hollow cast-iron plug is then turned or ground to correspond to the hole and used as a gauge to which the inside of the hole is scraped until it is true and round. The pin or shaft is then accurately fitted to go in freely to within a certain distance of its final location, generally from 1 to 4 inches; it is then pressed home.

The following example taken from actual practice serves to illustrate the method of making taper press fits. An engine shaft 22 inches in diameter had a shoulder on each end for its flywheel and crank, respectively. The flywheel had a bore 30 inches long which was scraped so that the shaft, which was tapered $\frac{1}{16}$ inch to the foot, would slide to within $4\frac{1}{4}$ inches of its location. The shaft was then pressed in the remaining distance. The bore in the crank was $18\frac{3}{4}$ inches in diameter and 14 inches long; the shaft, which was tapered $\frac{1}{16}$ inch to the foot, was fitted to go within $3\frac{1}{2}$ inches of the shoulder and was then pressed home. Similarly the crankpin, which was also tapered $\frac{1}{16}$ inch to the foot, had a bearing $9\frac{3}{4}$ inches in diameter, and 11 inches long and was fitted so as to go within $2\frac{1}{8}$ inches of its seat in the crank, being pressed on the remaining distance.

13. Shrink Fits.—In the absence of a press, the shrinking process is often resorted to, but in general it is neither as safe nor as satisfactory. In this process the internal piece is made larger than the hole it is to go into, and the external piece is then expanded by heat to allow the internal piece to be easily slipped in.

The amount to allow for a shrink fit is largely a matter of judgment, in which the material and the construction of the article must be taken into consideration. Krupp allows .01 inch to the foot of diameter in shrinking on locomotive tires, while American builders allow a little more, .012 inch in 1 foot being common practice. The values given in Table I for shrink fits allow .009 inch to the foot, which is a little lower than the values just mentioned. Care should be taken not to allow too much, since either the external piece may pull itself apart or the internal piece may be crushed or distorted.

14. Heating Work for Shrink Fits.—There are many ways of applying the necessary heat for shrinking purposes. In some instances the piece to be heated is supported by fire-brick or otherwise over a suitable fire, perhaps being covered with sheet iron or asbestos to assist in retaining the heat. Again, a ring of gas pipe may be provided with holes projecting radially inwards or outwards as required, the jets of flame impinging on the work. If a large number of duplicate pieces are to be assembled, regular furnaces may be employed.

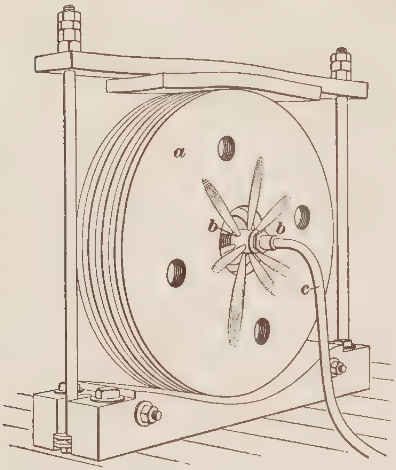


Fig. 3

A very convenient burner for heating parts in making shrink fits is shown in Fig. 3. A piston *a* is clamped between two wooden pieces, as shown in the illustration, and a gas burner *b*, which embodies the principle of the Bunsen burner, is supported centrally in the piston-rod hole. The burner has a number of holes in its circumference producing as many jets of flame as there are holes, which strike the surface to be heated. An ordinary rubber gas tube *c* connects the burner with a gas pipe on the wall.

15. Sectional Keys for Shrinking.—In shrinking together two pieces that have key seats that must line with each other, a device known as a sectional key may be advantageously used for alining the pieces. One form of this device is shown in Fig. 4. Two tapered side keys *a* and *b*, having handles a' and b' of suitable length, are placed in the two key seats of the two parts that are being shrunk together; and when these parts are in place, a tapered key *c*, with a long handle c' is then driven in between them, thus forcing the side keys against

the sides of the key seats and alining them. When the work has cooled off, the device is removed, and the permanent key fitted and driven home.

16. Examples of Shrinking.—To shrink a crankpin in, the pin is turned to the required size and the crank is then heated sufficiently to allow the pin to enter freely. Care must be taken here to guard against the pin sticking in the hole before it is clear in. A heavy sledge should be provided on both sides of the crank, as the pin may require a little driving to carry it clear home. If the crank should cool too rapidly, the pin must be backed out as quickly as possible. When once in place, the pin should be kept cool by applying waste soaked in cold water or by keeping a stream of cold water flowing on the pin. If the pin gets hot, it may expand the hole and the fit will then not be as tight as was intended.

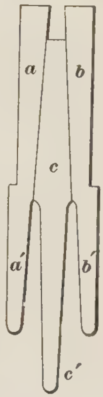


FIG. 4

17. The shaft should be blocked up at a convenient distance from the floor, with the key seat up. The crank should be heated until the bore shows sufficient expansion to go on the shaft easily. If the crank is heavy, it should be picked up by a crane in such a position that the key seat will be on top, to conform to that in the shaft. All dust or dirt should be carefully brushed from the crank, which should be quickly shoved up to the shoulder on the shaft, and a temporary key, fitting sidewise, should then be lightly driven in to keep the key seat in line. Means should be provided for holding the crank against the shoulder, or it may slip back and grip the shaft so tightly that it can never be brought up into its correct position. The permanent key may be fitted after the crank is cooled.

INSPECTION OF WORK

18. Raw and finished materials are frequently inspected in testing laboratories, inspection bureaus, or by inspection engineers. All goods inspected are marked with a label or trade-mark. Among the items usually inspected by these firms are rubber-covered cables and wires, porcelains, cements, hardware, tubing, sheet steel, conduit, steels of all kinds, castings, electrical apparatus, etc.

19. While all the large concerns have their own inspection departments they are obliged to engage outside experts from time to time, either because their own experts are not well qualified to pass on certain raw materials; because a preliminary inspection must be made at a place which their own experts cannot reach readily; or because of the requirements of the customer.

The building up of an efficient inspection corps requires a long time and is expensive, and for these reasons small concerns frequently find it to their advantage to engage the services of reliable inspection bureaus.

20. Inspection of Raw Materials.—The work of inspection may be divided into three kinds, inspection of raw materials, inspection of work in progress, and inspection of finished products.

21. As an aid to the purchase of the proper raw materials and their subsequent inspection when received, many of the larger concerns prepare so-called purchasing specifications, which set forth the physical requirements to be met, tests, guarantees, etc. Where an extensive variety of subjects is covered, the preparation of such specifications is a never-ending work of tremendous magnitude, as the list must be constantly revised and augmented. Some items do not lend themselves to a complete description by specification; for example, lubricating oils for shafting and machine tools; felts of the proper elasticity or springiness; articles of any kind with the correct finish, etc. A reference sample of each item of this kind is

usually kept in a storeroom of approved materials, where it can be used for comparison as consignments are received from time to time. Similar samples may likewise be forwarded to suppliers for their use. On the receipt of materials at the works, they are inspected and tested as set forth in the specifications or otherwise deemed necessary.

INSPECTION OF MATERIALS RECEIVED

Purchasing Agents' No.__________ No.__________

Requisition No.__________ Date__________

From Whom Purchased____________________

Description

Quantity	The Storekeeper is notified that the articles listed below have been {accepted / rejected—defects are stated on reverse side

Signed____________________

FIG. 5

22. Fig. 5 shows a form of inspection blank adapted to material, whether raw or finished, purchased outside and inspected on its arrival. On this blank a space is provided for the number of the card, the date, the purchasing agent's order number, the requisition number, and the name of the firm from whom the articles were purchased. Under the word quantity, the inspector writes the number of articles that have been inspected. If they are satisfactory, a line is drawn through the word "rejected" and the blank is signed. If the goods are not satisfactory, a line is drawn through the word "accepted," the defects are listed on the reverse side of the blank, and the blank is signed. All materials falling short of the standards set by the specifications are rejected and the suppliers notified at once, so that there may be the minimum loss of time in replacing them.

23. Limits of Accuracy Required in Finished Work. In the shop, the dimensioned drawings are largely used by the

shop inspectors. Formerly, it was the custom to place on drawings single dimensions only; for example, if a shaft was to be 3 inches in diameter and 10 feet in length, these dimensions were specified on the drawing. But it is beyond human skill to make a shaft absolutely 3 inches by 10 feet; and, as a matter of fact, such accuracy would not be required even if within the limits of possibility. The shaft will, when completed, be found either a little larger or a little smaller than the exact dimensions, and experience will determine just how great the variations may be without making the piece defective. This being the case, the permissible allowance both above and below exact size should be given on the drawing. When this is done, not only will the workmen have a guide to work by, but the inspectors will have one as well, and there will be no cause for perplexity on the part of any one connected with the work as to whether or not it should be passed.

24. Inspection of Work in Progress.—For best results, all work should be inspected as it progresses through the shop, if possible while actually being machined, assembled, or otherwise worked on. This course is recommended in preference to waiting until a piece is finished, for frequently errors may thus be caught before much material has been spoiled. In many cases it will be unnecessary to inspect every piece, as for example in screw-machine or other automatic or semi-automatic work. A few pieces inspected at the beginning of a job, to see that the dimensions check with the drawing, and a few additional pieces inspected as the work continues, to guard against wearing of the tools, will be sufficient. Where a piece undergoes a sequence of operations, each operation being dependent on the accuracy of the one preceding, a check on the first operation will prove sufficient.

25. Inspection Bench, Rooms, and Tags.—When apparatus or parts are manufactured in large quantities, use is made of dies, limit gauges, templates, etc., and such inspection is therefore a comparatively simple matter. In many instances, it is only necessary that certain dimensions be exact and these alone are checked. Where material cannot be inspected during

its manufacture, it is a good plan to have it delivered to an inspection storeroom. Here it can be inspected for quality as well as checked for quantity. When the work is too bulky to permit this to be done, it should be sent to the inspector's bench or inspected while on the floor near the machine on which the work is done. When large or medium-sized work is made in quantities, a serial number may be assigned to each piece and this number placed on the time slip or job ticket of each workman who is engaged on the job. In this way any defect may be traced back to the right workman regardless of the elapsed time between manufacture and inspection. Inspection tags should be used after each inspection unless the pieces are otherwise marked by an inspector's stamp, and a single tag may often be employed for a quantity of small items. Considerable aid may be rendered the inspection force by the manner in which these tags are designed. They should not consist simply of a few ruled lines on which the inspector is to write the name of the piece, the date of inspection, and sign his name at the bottom. On the contrary, a list of the vital points to be watched by the inspector should be printed in the form of questions which can be answered, wherever possible, by a simple *Yes* or *No*. This is illustrated by the tag shown in Fig. 6, used in connection with the testing of railway motors. A scheme of this kind will prove of the greatest value, especially when the inspector is comparatively new at the work. Where the work is of miscellaneous character, the plain tag must, however, be used.

26. Judgment Required of Inspector.—In addition to all rules, helps, or guides for the assistance of inspectors in their work, judgment must at all times be used by them. A knowledge of the application to which each piece undergoing inspection is to be put, is almost essential if it is to be passed or rejected on its real worth. If the piece is a rough casting or forging and no finish is required, the variation from the drawing may be very considerable, perhaps a quarter-inch, or even more if the piece is of large size, and no harm will probably be done; in fact, any expense incurred in bringing the piece to the size specified on the drawing would be an absolute waste of time and

money. On the other hand, if the press-fit portion of a generator shaft was under inspection, a very close adherence to specified dimensions, possibly within .001 or .002 inch, would be necessary; otherwise, the shaft might, if under size by the amount stated, be actually loose when in position, or if oversize by an equal amount, might rupture the generator spider. It will thus be seen how large a part good judgment plays in inspection

COMPLETE MACHINE

Has frame been cleaned and painted inside?_______________________

Are field coils tight and is bore of field correct?____________________

Are poles evenly spaced?______________________________________

Do interpole bolts extend beyond pole face?____________________

Are connections between field coils properly cleaned and insulated?_______

Has flame-proof braid been removed from brush-holder leads and replaced by tape?____

Are housings entirely free from dirt and core sand?____________________

Do bearings and housings fit and is alinement correct?___________________

Are oil grooves chipped in cells?__________________________________

Is drain hole provided for waste oil?_______________________________

Are brushholders properly spaced and is the brush tension correct?_______

Are brushes parallel with commutator segments?______________________

Are all covers properly fitted?____________________________________

Is pinion tight on shaft and key properly fitted?______________________

Does gear case clear gear?____

Did commutator develop high-bar on test?___________________________

Serial____

Order____

Inspected by___________________________

FIG. 6

work; and, without going into further explanation, it may simply be stated that the same good judgment must also be used in dealing with the workmen. It is therefore quite evident that every mechanic has not the necessary requisites of a good inspector and that this position, being of equal importance with that of foreman, calls for the best men available.

27. Study of Defects Disclosed by Inspection.—If the full value of inspection is to be obtained, a careful study of

all defects found by the inspectors must be made. To this end daily reports should be forwarded by each inspector to the head of his department, who should classify them in various ways according to classes of apparatus and parts, manufacturing departments in which they occur, also as to whether due to design, workmanship, material, clerical errors, changes made by purchaser, etc. Such a complete analysis of defects will indicate to those in authority where the troubles lie and how serious they are, with a view, first, to correcting the defects before the apparatus leaves the shop, and, second, to take such steps as will prevent their recurrence. Besides the direct money loss due to various defects in apparatus, there is also the loss in output, the demoralizing effect on those engaged in the work, the delay in shipments and, if the defect gets past the inspection force, the effect on the purchaser. It is an axiom of every business concern that it pays to advertise and the best possible advertising medium is a pleased customer. It is equally true that a displeased customer can sometimes offset the good effect of large amounts spent in advertising.

EXAMPLES OF ERECTING

ERECTION OF LARGE WHEELS

28. Lining Up Fylwheel Shaft.—Large flywheels, rope wheels, gear-wheels, and other similar wheels are usually assembled in the erecting pit. The assembling and machining of the rim of a large built-up flywheel is an excellent example of the use of the erecting pit. The following method of doing this work may be used: Parallel bars *a*, Fig. 7, are bolted opposite each other to the plates surrounding the mouth of the pit, and temporary bearings *b* that will bring the center of the shaft *c* about 30 inches above the floor level, are placed on top of the parallel bars so that they are fairly in line with each other. The shaft *c* with the hub *d* on it is now picked up by a crane and lowered into the bearings, which are properly

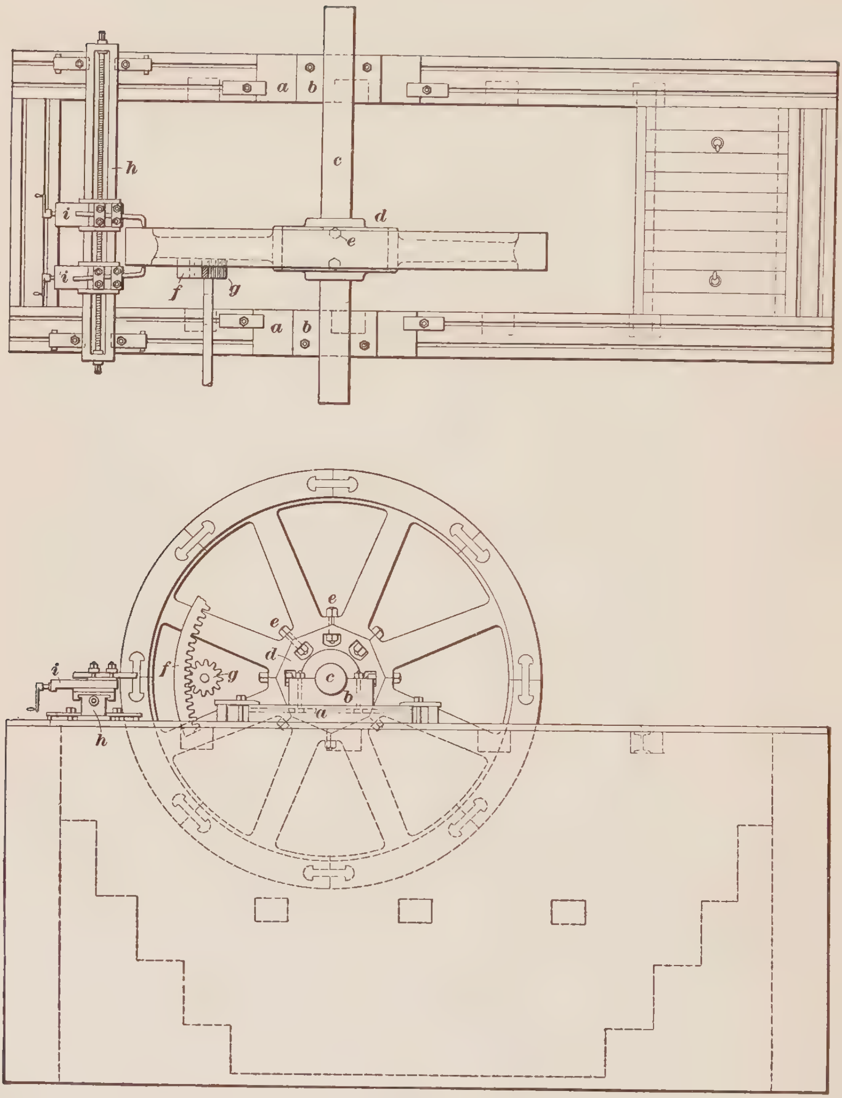


FIG. 7

alined to suit the shaft. The bearings, which need no caps, are now bolted down to the parallel bars. Another method of setting up the work consists of blocking up the shaft until it is level; the bearings, which are considerably larger than the journals, are then shifted into place, bolted down, and Babbitt metal is poured into them around the journals.

29. Assembling Rim Sections of Flywheel.—All the faces of the sections of the rim having been properly machined prior to the erection, one section is picked up by the crane and gently lowered on the hub, to which it is fastened, by temporary bolts, while in a vertical position. The shaft is now revolved sufficiently to bring the next seat of the hub to a horizontal position, and after the fastened section has been securely blocked to prevent rotation of the shaft, another section is lifted into place and is attached to the hub and the first section. This operation is repeated until the wheel has been assembled. The holes in the arms and hub are now reamed one by one to match exactly, and the permanent bolts are then carefully fitted, driven home, and the nuts securely screwed up, as shown at *e*, Fig. 7.

30. Turning Sides and Face of Rim of Flywheel.—To turn the sides and face of the rim, means must be provided for revolving the flywheel. A common method is to bolt a large annular gear, which, for convenience, is made in short sections, to the arms of the flywheel. One of these sections is shown at *f*, Fig. 7. A pinion *g* is then placed in mesh with the gear and is driven either by a rope drive, by a belt from an overhead shaft, by an electric motor, by a small steam engine, or by a compressed-air engine, as is most convenient. A heavy bed *h* is then bolted across the pit; it may carry two slide rests *i* to allow both sides of the rim to be finished at once.

31. Polishing of Rim of Flywheel.—If the flywheel is to have the rim polished, a grinding rig carrying a suitable grinding wheel may be mounted on the carriage *i*, Fig. 7. The grinding wheel, which is driven in any convenient manner, is then fed slowly across the surface that is to be ground while the fly wheel is revolving at a suitable speed.

ERECTION OF LATHES AND PLANERS

LATHES

32. Systems of Erection.—The method of erecting lathes varies greatly in different shops and also with different sizes and designs. Some makers first plane the grooves in the headstocks and tailstocks to a gauge and then bore the boxes of the headstocks and the holes for the tailstock spindles, while others reverse the operation, first boring the boxes and the holes in the tailstock spindles and then planing the grooves in the bottoms of the headstocks and tailstocks. Both systems, or modifications of both, are frequently used in the same shop. The second system is generally used on small lathes, up to 18 inches swing, while in larger lathes the first-mentioned system is more common.

33. Seasoning Beds.—Where extremely accurate lathes, such as toolmakers' lathes, are to be made, the beds should be cast several weeks before they are to be used, and allowed to season. This seasoning consists in simply piling them in some convenient place in such a way that they will not be subjected to any outside forces, and allowing the stresses in the casting itself to become equalized. Where extremely accurate work is required, a roughing cut is taken off the surfaces to be planed and the beds are again allowed to season for a short time before being finished.

34. Machining Beds.—Lathe beds are generally finished on the planer. The **V** grooves, guides, or shears are usually planed to gauges. The outside edges of the bed and the flat top between the ways are also planed. After the work leaves the planer, the space between the grooves, the outside edge, and the flat top of the bed should be filed and polished as soon as possible, as they can be finished much easier and in less time immediately after planing than when the work has been exposed to the air of the shop for some time. The file takes hold of the freshly planed work better than it does after the surfaces have

become slightly rusted. Some mechanics claim that a file does not take hold of the surface of a casting that has stood for some time after planing because the surface becomes covered with a thin coating of grease that is deposited from the air of the shop.

35. Testing and Scraping Beds.—The ways are usually tested by a straightedge and then scraped, or, if necessary, they are filed and scraped. However, one shop, in which small lathes are made in lots of from twenty-five to one hundred at a time, uses a special surface plate made as shown in Fig. 8 for each size of lathe. This surface plate has been fitted up with great care, so that both the top and bottom ways *a* and *b* match each other; it has a trunnion at each end and can be lifted by a chain block or air lift. The hoist is connected to the surface plate by a bail; that is, a yoke-shaped handle of such con-

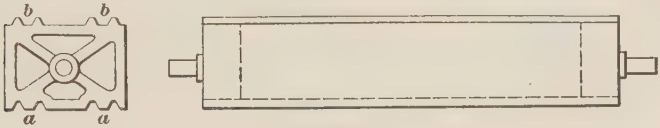


Fig. 8

struction that it may readily be secured to the plate. The trunnions permit the plate to be turned with ease, either side up. The ways on the lathe bed are scraped to fit the grooves *a*, and the headstock, tailstock, and saddle are scraped to fit the ways *b*. The saddle is sometimes scraped to the ways on the bed.

36. Machining and Fitting Headstocks and Tailstocks.—The headstocks and tailstocks of small lathes are frequently made ready for the boxes and caps by milling, while the larger sizes are planed, machining them if possible by the gang system; that is, a large number are put on the planer table in line, and all are machined together. Jigs are usually provided for holding the pieces on the milling machine, and may also be employed on the smaller sizes when the work is done on the planer. The legs are fitted and bolted to the bed at any convenient time, but generally before the ways on the bed are scraped.

The machined castings for the headstocks and tailstocks are next sent to the fitter; the boxes and caps are then fitted to the headstocks, and the tops and bases of the tailstocks are fitted to each other.

37. Boring for Headstock and Tailstock Spindles. There are two general systems for boring the holes for the spindles in lathe headstocks and the tailstocks. In the case of small lathes, the boring is usually done first, after which an arbor is placed in the bored holes of both headstock and tailstock. This arbor is made to fit the holes in both accu-

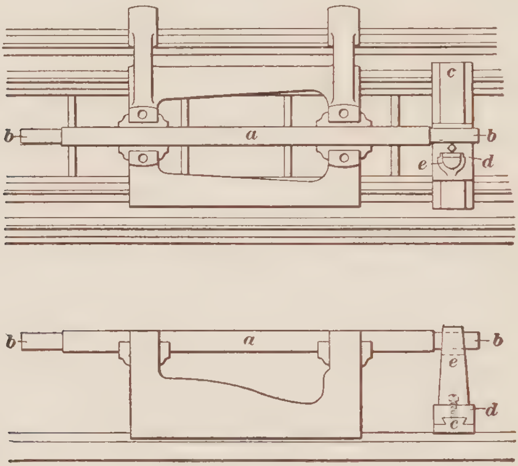


FIG. 9

rately, and serves to bring them into line. While the pieces are held in line by means of the arbor, the **V** grooves are planed in them. In the case of larger lathes, the **V**'s are usually planed first and the headstock and tailstock fitted to the ways on the bed. After this, a special fixture carrying a boring bar is used for boring the holes in the headstock and tailstock. This fixture is constructed so that it holds the boring bar parallel to the **V**'s or ways of the lathe. A special jig may be used for holding the headstock and tailstock while boring, instead of putting them on the bed. After the boring is completed and the **V**'s are planed, the work of erecting actually begins.

38. Fitting Headstock and Tailstock to Bed.—Lathe erection differs somewhat in different shops, but the following may be taken as the general method of procedure: The bed, with the legs attached, is placed in position on the erecting floor and leveled until it is out of wind. The **V**'s or ways are tested by means of straightedges and suitable gauges. The headstock and tailstock are then scraped to fit the **V**'s.

When the headstock and tailstock have been brought to fit the **V**'s fairly well, their spindles are brought into alinement by means of proof bars, as shown at *a*, Figs. 9, 10, and 11. These proof bars fit the boxes of the headstock and the bore of the tailstock spindle. The ends *b* of the proof bars are finished by grinding to exactly the same diameter, so as to allow them to be used in making measurements for alinement.

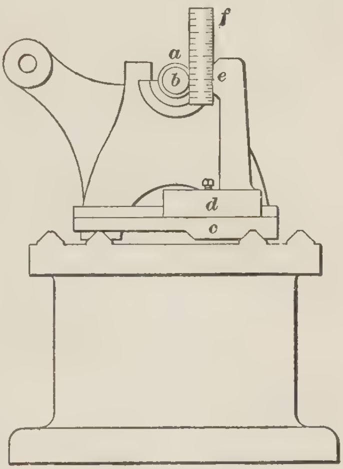


FIG. 10

39. When making measurements for horizontal alinement the special saddle *c*, Figs. 9 and 10, is used. This saddle is provided with a groove fitting one of the **V**'s of the bed, and carries a slide *d* to which an upright arm *e* is fastened. The headstock and tailstock with the proof bars in them are placed on the bed at some distance from the ends. The temporary saddle is placed near one end of one of the proof bars, and the slide *d* is adjusted until the feeling piece, as, for instance, the steel rule *f*, will just fit between the face of the upright *e* and the end *b* of the proof bar. The saddle *c* is then shifted to the other end of the proof bar, and the distance between *e* and the end of the proof bar tested, without disturbing the position of the upright. This operation is then repeated for the other proof bar. The manner in which the feeling piece goes in shows whether the headstock and tailstock are in perfect aline-

ment in a horizontal plane. If not, the grooves that fit on the **V**'s of the lathe are scraped until the piece that is out of alinement is brought into perfect alinement. Sometimes a machinist's indicator or some form of micrometer head is carried on the upright *e*. Such a device as this serves to measure the amount that the spindles are out of alinement.

40. To test the vertical alinement of the spindles, a jack *g*, Fig. 11, may be placed on top of the parallel *c* and the screw adjusted until it will just touch one end of the proof bar. The parallel and the jack are then shifted to the other end of the proof bar. The manner in which the jack goes under the bar

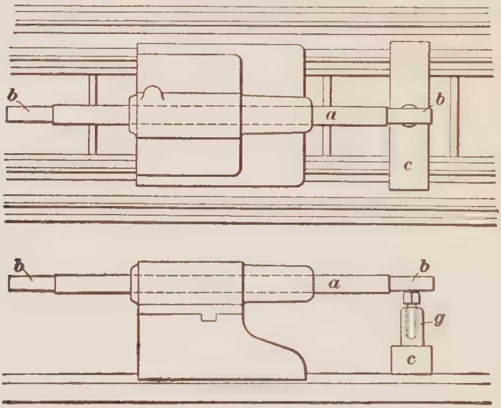


FIG. 11

determines which way, if any, either end of the spindle is out of line. This method not only tests the alinement of the headstock and tailstock spindles in respect to each other, but at the same time tests their alinement with the ways or line of motion.

41. Fitting Saddles.—After the headstock and tailstock are lined, the saddle is placed on the **V**'s and a round test piece *a*, Fig. 12, is placed against the cross-slide *b*. This test piece should be ground exactly cylindrical and should be long enough to project several inches beyond the sides of the saddle. An arm *c* is now fastened to the proof bar and the setscrew *d* brought in contact with the bar *a*. The arm *c* is then rotated to the

opposite side, to the position shown by the dotted lines. If the screw *d* does not show the saddle to be square, it must be shifted by scraping the **V**'s in the saddle until the cross-slide *b* is at right angles to the **V**'s, as shown by the test bar *a* and screw *d*.

42. Assembling Parts of Lathe.—After the headstock, tailstock, and saddle are brought into alinement with the **V**'s, the tailstock spindle and anchor are added to the tailstock, and the spindle, back gears, feed-mechanism, and feed-reversing mecha-

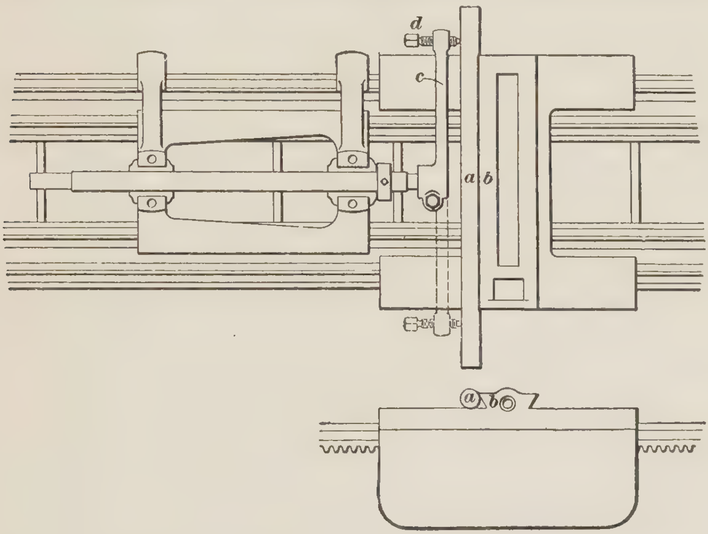


FIG. 12

nism are placed in position on the headstock. The set-over screws must be in the tailstock while lining the tailstock spindle if the two spindles are to be brought into line with each other.

43. Fitting Apron.—The apron is next clamped to the saddle and tested for alinement by using a proof bar placed in the lead-screw or feed-rod bearings. Measurements for alinement are taken from the bar to the edge and to the top of the bed. If necessary, the apron is brought into alinement by filing its top and back. The apron is then secured in position by screws, and the boxes for carrying the lead screw and feed-rod are placed

on special bearings provided on the ends of the apron proof bar. The boxes are then moved into contact with the pads on the bed, which have been provided to carry them. These pads have been previously planed, and the boxes are marked and then planed to fit on the pads, after which they are fastened to the bed, and the feed-rod, the lead screw, and the remainder of the feed-mechanism and screw-cutting mechanism are put in place.

44. Taper Holes in Headstock Spindles.—The taper hole for the center of a live spindle is put in by different methods; its accuracy is sometimes very intimately connected with the assembling or erection processes. Some makers prefer to rough out the spindle, particularly if it is a small one, and then to drill, ream, and hand ream the hole, after which the spindle is centered by the hole and trued outside, a plug having been fitted to the taper hole.

45. Another method that has many advantages is used extensively for large spindles. The spindle is centered and a steady-rest seat is turned on both ends, if it is to be a hollow spindle; the hole is then put through. Plugs are driven in both ends if the hole is larger than an ordinary lathe center, and the spindle is finished with the exception of the face-plate thread and the taper hole. The assembler or erector puts the unfinished spindle into its place, and if a large number of headstocks are to be finished, he places them successively on a lathe bed made for the purpose and provided with a taper attachment, and bores the taper hole true, smoothing it with a hand reamer. He completes the work by cutting the thread to fit the face plate. In large lathes built in small quantities, the headstock is mounted on its own bed for boring the taper hole in the spindle and for cutting the thread; a compound rest is used for boring the hole in case the lathe has no taper attachment. The process by which the spindle is finished in its own bearings has the important advantage that with reasonable care and skill on the part of the erector the taper hole and the thread will be concentric with the bearings of the spindle.

46. Patching Chipped Castings.—In the handling of heavy castings, chips or flakes are often knocked off by acci-

dental collisions with other work. While the machine may not be weakened appreciably, such defects are unsightly, and for the sake of appearances should be remedied. There are compounds on the market especially prepared for this work. The compound is made up to the consistency of putty, and is pressed over the defacement and allowed to harden. When once hard, it adheres firmly and may be filed like iron. It then presents a metallic surface.

47. Inspection.—All machines are more or less defective, as it is practically impossible to make anything absolutely perfect. Knowing this, the builder establishes a limit within which the error will not materially affect the working of the machine, and furnishes the inspector with a list of such defects and their limits, with instructions not to allow a machine to pass until the errors have been brought within the allowable limits.

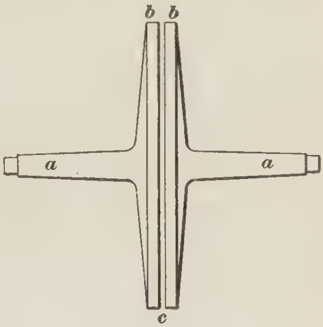


FIG. 13

48. The tapered hole in the headstock spindle is tested by means of a proof bar, to see whether it is concentric with the spindle journals. This bar is ground tapering to fit the hole in the spindle and is cylindrical the remainder of its length. It may project a foot from the spindle for the smaller lathes and more, proportionately, for the larger ones. By revolving the spindle and applying the indicator to the bar at the mouth of the hole and again at the outer end, the amount of error is easily determined.

The alinement of both spindles in reference to each other may be tested by means of the pair of disks shown in Fig. 13, which are made with taper shanks a that fit the taper holes in both spindles. The disks b are ground to the same diameter and are faced as square as possible. They are placed one in each spindle; the tailstock is then moved up to the headstock, and when the faces c of the disks are brought nearly in contact the amount of error is readily measured with a thickness gauge.

A pair of centers, having cylindrical ends exactly the same size, with the ends faced square, are sometimes used by the erector to determine if the spindles are in line. One is placed in each spindle, and the two, when brought up end to end, show very closely any error in alinement.

49. The leadscrew, being particularly liable to error, is tested for any deviation from the true pitch in lengths of 12 inches at different points along the screw. Gearing of all sorts is inspected and tested for alinement and smoothness of operation. The fits of all wearing surfaces are tested, as well as the fits of the various screws and binding and clamping fixtures. No part is neglected, and no defective material or faulty workmanship is allowed to pass.

The inspector is usually provided with a printed blank for reporting each lathe. The serial number stamped on the lathe appears on the report, which is filed in the office for reference should complaint be made or repairs ordered.

50. Filling and Painting Machines.—Most machines are finished by a coat of paint. The surfaces of the castings are cleaned first in the foundry scratch room, and any remaining dirt or irregularities and unevennesses of joined parts are removed during erection by chipping and filing so far as may be necessary to make a good surface. The shop painter next goes over the surfaces with a filler, which is a thick, heavy, very adhesive, and quick-drying paint. It is applied with a putty knife, as it is about as thick as very soft putty or freshly opened white lead. This filler hardens rapidly when exposed to the air. The filled surfaces are then smoothed by wetting and rubbing them with a piece of grindstone or of a broken emery wheel, or by simply rubbing them with coarse sandpaper. When the smoothing has been finished, one or two coats of paint of the desired color are applied. Green paint is preferred by some builders and shop superintendents, as it gives a lighter appearance to the shop than black paint. Green and even lighter paints are much used for machine tools, and if the painted surfaces are covered with a varnish that will resist oils, they are easily kept clean and the general appearance of

the shop is thus much improved. Steel-gray metallic paint is preferred by some builders owing to the attractive appearance it gives to the machines.

PLANERS

51. Shop Erection.—In planer erection the principal points to be considered are that the method must be such as to quickly and cheaply assemble the parts so that they will all be in their proper relation to each other and that the alinement of the various parts will be perfect within the required limits. Small planers can be erected much easier than large ones, because there is less spring in their beds. When manufacturing small planers, the parts may be so accurately made by means of gauges and templets that they can be assembled and made practically interchangeable. In the case of large planers, the parts cannot be made interchangeable, as the bed depends on the foundation for its support, it being impracticable to make a casting large enough to insure perfect rigidity in the bed. Hence, in the case of large-sized planers, each machine must be treated by itself. All the points in the erection of a small planer are involved in the erection of a large planer, as well as many other complicating factors; consequently, the erection of a planer of this class will be given in detail.

52. Planers may be divided into three classes: *small*, which plane work up to 24 inches square, that is, in width and height; *medium-sized*, which plane work from 24 to 40 inches square; and *large*, which plane work larger than 40 inches square. Small-sized planers are usually provided with a single head for carrying the tool, the head being placed on the cross-rail between the housings. Most medium-sized planers have two heads on the cross-rail. The larger planers are all provided with two heads on the cross-rail and with one head on each upright.

53. Planers may also be divided into two classes in regard to their construction; that is, into those having double housings, or *closed* planers, and those having but one housing, or *open-side* planers. The erection of these types as far as the general principles are concerned, does not differ greatly; the

erection of the closed type involves the bringing of the housings parallel, and hence planers of this type will be considered.

54. Precautions in Regard to Castings.—All castings for planers should be made from good close-grained iron. The castings for the table should be of a soft but tough nature, so that the upper surface can be planed true at one setting of the tool, for if the casting were hard it would wear the tool enough to throw the surface appreciably out of true. Very large planer beds, and occasionally large planer tables, are made in two or more pieces and joined by means of bolts and dowel-pins.

55. All the larger castings for the planer should be planed to carefully tested gauges, and every angular surface tested to make sure that the angle is correct. The work should be tested with a straightedge on the machine to make sure that the planer is not working concave or convex. Care taken in planing these parts will reduce the work of the fitter and erector. Long beds or tables that are made in sections should have their ends planed perfectly square and should be bolted together as securely as possible with fitted bolts and dowels. After all machine work is done, the erection proper begins.

56. Supporting of Bed.—The planer bed *a*, Fig. 14 (*a*), is supported on cast-iron parallel blocks *b* placed 6 or 8 feet apart along the whole length of the bed. Planed cast-iron wedges *c*, arranged as adjustable parallels, may then be placed between the parallel blocks *b* and the bed.

A better form of adjusting block used by some builders is similar to the block shown in (*c*). It consists of a base *a* having an inclined surface *b* on which the tapered adjusting block *c* slides. The top, bottom, and inclined surfaces are planed true. Adjustment is made by moving the adjusting block in or out by means of the adjusting screw *d*. The lugs *e* are slightly higher than the slide and act as stops when brought against the edge of the bed. A clamp jack *d*, Fig. 14 (*a*), is placed under the bed at each side just forward of the housings. This may be removed if necessary while putting in the driving gearing. The blocking under the uprights should be so arranged that

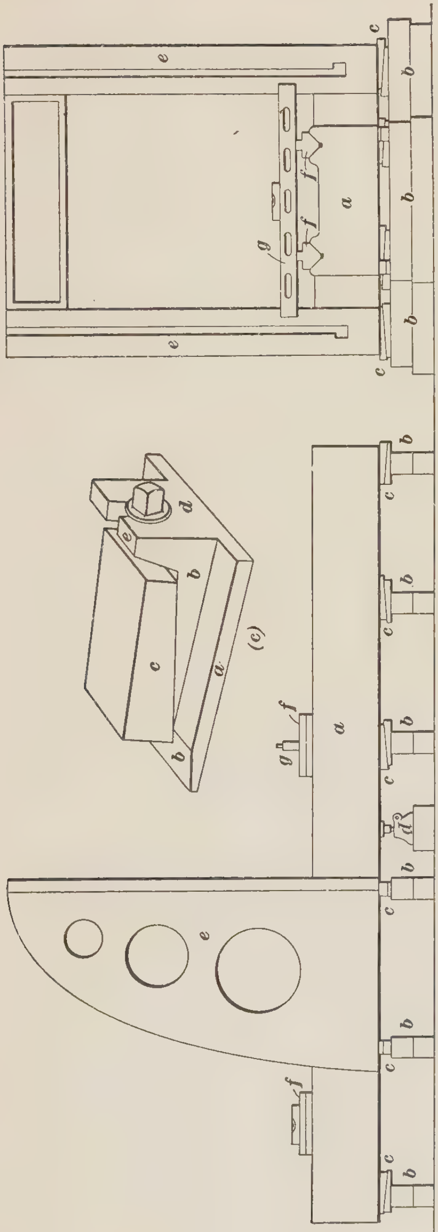


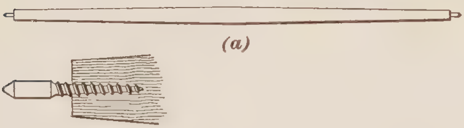
Fig. 14

it will not interfere with the driving and feed-mechanism during erection. As these details vary, the blocks must be arranged to suit each different machine. It is best to put the housings or uprights *e* in their places on the bed before the leveling operation, as the addition of their weight may throw the bed out of level again if they are placed in position afterwards. In some cases the uprights *e* are supported on erecting jacks in place of blocking, as this facilitates adjustment of the parts during leveling.

57. Leveling of Bed.—Several methods may be followed in leveling a planer bed, depending on the tools at hand. They all require considerable care. The process here described will give very good results if the work is carefully done. The

leveling is done as follows: A pair of **V**-shaped parallels *f*, Fig. 14 (*b*), about 3 feet long, are placed one in each of the ways or **V**'s of the bed. These parallels have been scraped as nearly true as it is possible to make them, and they may have center lines on them. A sensitive level is used on the top and one side of the bed is carefully leveled by moving this parallel, short distances at a time, over the entire length, adjusting the wedges under the bed where necessary. The other parallel is used in a similar manner in the other **V**, and by placing a straightedge across both of the parallels and using the level on it, the work is leveled crosswise. The operation of first leveling one side and then cross-leveling to the other is repeated until no further errors can be detected.

58. Setting of Housings.—The housings *e*, Fig. 14 (*b*), are now tested and brought exactly plumb by placing a straightedge across the blocks lying in the **V**'s and using a large square on the straightedge. In the case of large planers having a very heavy cross-rail and heads, some makers do not attempt to bring the housings exactly plumb on their faces, but allow them to lean back .0005 inch for every foot in height, as the weight of the cross-rail and heads will bring the housings forwards somewhat, and this allowance will about correct the error. The housings are squared both sidewise and in front, and the distances between them at the top and bottom are made equal.



(*a*)

(*b*) FIG. 15

59. In gauging the distances between housings on a large planer, use may be made of a large adjustable pin gauge illustrated in Fig. 15 (*a*), which consists of a bar of white pine or some other light wood, fitted with a screw inserted endwise at each end. The bar should be $1\frac{1}{2}$ to 2 inches shorter than the distance between the housings, and the screws may be simply $2\frac{1}{2}$-inch wood screws with their heads filed off and the ends pointed and rounded, as shown in detail in Fig. 15 (*b*). The bar may be tapered from the center toward both ends, and in

the case of a rod for measuring a distance of approximately 10 feet, the wooden bar must be about $1\frac{1}{2}'' \times 2\frac{1}{2}''$ in the center. The advantages of the wood are that it is lighter than metal and that it is affected less by expansion and contraction due to varying temperature. No fixed distance is made between the housings on a large planer, the only object being to make it the same at the top and the bottom, and this device becomes only a large inside caliper.

60. During the operation of setting the housings parallel the gauge is first set to the smallest distance, whether it is at the top or bottom. The gauge is then moved to the wider end and the approximate difference between the two ends found by putting strips of paper or sheet metal between the end of the gauge and the housing. The housing bolts are then slackened off and strips of paper or thin sheet metal placed between the bed and the housing so as to bring the latter parallel to the other housing when the bolts are tightened. The thickness of the material inserted will depend on the amount the housings are out of parallel. This process is repeated until the housings are correctly set, the gauge being adjusted from time to time as necessary. The thickness of the strips inserted is then measured with a micrometer and an equal amount of metal filed or scraped from the side of the bearing surface opposite the side where the strips were placed. The bolts are then tightened and the distances again gauged. If now the housings are found to be the same distance apart, top and bottom, the adjustment is correct.

After the housings are perpendicular to the bed and parallel to each other, the arch, or top rail, is squared off to the length indicated by the gauge and bolted in position. In the case of large planers, no attempt is made at interchangeability in this respect, but each top rail is fitted to the planer on which it is to be used.

61. Placing Table and Driving Mechanism.—The ways on both table and bed are finished by removing all loose metal and scraping them until they fit and have good wearing surfaces. The driving mechanism and the table are then put in place, after which the table rack is planed to the required thickness and secured to the table.

62. Squaring Cross-Rail.—The cross-rail *d*, Fig. 16, must be set true to the **V**'s in which the planer table slides. One way of accomplishing this is illustrated in the figure. The table *a* is run back far enough to expose the **V**'s under the cross-rail and two cylindrical pieces *b*, *b′* of exactly the same diameter are laid in the **V**'s. A square-nosed tool *c* is set flat in the tool post and brought over one of the cylinders *b*. The tool is then adjusted until a feeling piece can just be moved between the cylinder and the tool. Another method is to use a machinist's indicator in place of the tool, and bring the point of the indicator in contact with the cylinder. The tool or indicator is now run to the opposite side of the planer and central over the cylinder *b′*. If *b′* is found to be higher or lower than *b*, the error must be corrected by adjusting one end of the cross-rail up or down, which may be done in a number of ways. Some makers find that a sufficiently close adjustment can be obtained by moving one of the gears *k* or *k′* one tooth, so as to raise or lower one end of the cross-rail this amount. Other makers leave one of the pinions *m* or *m′* loose until the adjustment has been made, after which they key it in place. Still others attach one of the pinions, as *m′*, by means of a setscrew, as shown at *n*, the setscrew being tightened after adjustment.

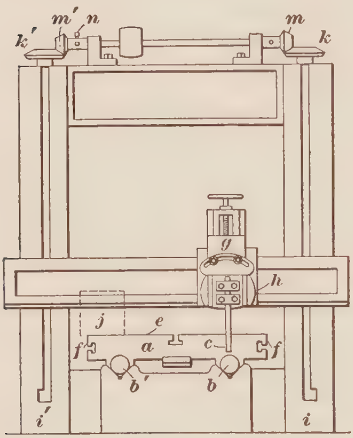


FIG. 16

63. As the cross-rail is moved up and down by two screws operated by the gears *k* and *k′*, when one end of the rail is found to be low, it should be raised the proper amount. When the setscrew method of adjustment is used, this can be accomplished by loosening the screw *n* and turning the loose pinion *m′* the desired amount. By repeating these trials the cross-rail can

be so adjusted that the tool and feeling piece, or indicator, will give the same reading over both cylinders b and b'. The vertical screws carrying the cross-rail should always be so adjusted as to raise the cross-rail, as this will take up any lost motion or backlash between the nuts, the elevating screws, and the uprights. Hence, it is always better to raise the low end of the cross-rail rather than to lower the high end. The feed-mechanism and the mechanism for raising the cross-rail by power, together with the oiling device, are all put in place and tested, after which the various planer motions are tested to see that they are within the allowable limits of error.

After the cross-rail has been adjusted, a light cut should be taken over the top of the table. The head g, Fig. 16, should then be set vertically by means of a square. On very large planers the table is not trued in place by the manufacturer, this being done after the planer is set up in the purchaser's plant.

64. Preparation for Shipment.—Small and medium-sized planers are generally shipped with the principal parts in place and all bright parts coated with slush oil, or some other protective coating, to prevent rusting. The lighter and small parts are crated to prevent breakage and the whole mounted on skids for convenience in handling. Larger planers are taken apart, the smaller pieces being boxed and the fitted faces of the larger ones crated. Finished surfaces should be slushed or given a protective coating before shipping. The smaller planers have their tables carefully trued in place before leaving the manufacturers, but the larger ones are usually shipped with the table just as it comes from the planer on which it was finished.

65. Erection in Place.—The top of the foundation for a large planer should be smooth and as near level as it can be made. The bed is placed in its correct position on the foundation and leveled by the use of leveling blocks or by shims placed between the bed and the foundation. A high-grade level should be used and the adjustment continued until the bed is level lengthwise and crosswise after the housings, arch, and cross-rail have been bolted and keyed in place. The cross-rail elevating mechanism is then placed in position.

The cross-rail is then adjusted until it tests perfectly level with respect to the **V**'s. The feed-mechanism may meanwhile be put in place. When the driving and feed motions are working satisfactorily, the **V**'s of both the table and bed are cleaned and oiled and the table is placed in position. The table is then tested and if it has not been already done, the top and working sides of the **T** slots are carefully trued. The head or heads on the rail are then set to plane square with the table. Each head is set as nearly vertical as possible by placing the beam of a square on the table and adjusting the side of the down-feed slide to its blade. Cuts are then taken down the sides of the table by side tools. The vertical setting of each head is adjusted, after each cut until the blade of a large try square will hold a slip of tissue paper at each end of the blade on the top of the table while the inside of the beam is held against the side face of the table. The setting mark *h*, Fig. 16, is then drawn on the saddle so that it coincides exactly with the zero mark of the graduations on the head. If the setting mark has already been placed on the saddle it is best to go through with the test to prove its correctness.

66. If the planer is provided with side heads on the uprights, they may be set from the table and tested by clamping a casting as indicated by the dotted lines at *j*, Fig. 16, to the surface of the table and planing the vertical surface true with the side head. The top is roughed off with a tool in the cross-rail head, and finishing cuts are taken over the top with the horizontal feed of the side head which is adjusted until the two planed surfaces are exactly square. The setting mark is then scribed on the saddle.

67. Securing in Position.—The weight of a large planer is sufficient to hold it in position on the foundation while resting on the adjusting blocks. Medium- and small-sized planers are usually set directly on the foundation and leveled by putting shims, or thin pieces of metal, wood, or paper, under the supports. When medium-sized planers are located, holes are sometimes made in the supporting surface so that round pins half an inch or more in diameter can be inserted close to the bed or legs to prevent any possible movement.

Small planers provided with legs or bases have holes drilled through the flanges of the legs or bases through which lag screws or expansion bolts pass and prevent end or side motion. They should not be drawn down tight or they may spring the machine. Many long planers are set permanently on adjusting blocks so that they may be tested and leveled as often as may be necessary to keep them level and in line.

The table of a planer should be tested lengthwise with a straightedge. If it is not straight, it will plane the work concave or crowning.

68. Small- and medium-sized planers are shipped with all their parts in place, but need as careful, though not as much, attention in erection as do the larger sizes, which must be assembled on their foundations. It is usually sufficient to drive wedges under the legs until the table is level. The cross-rail is then tested to see that it is parallel to the top of the table. If it is not parallel, the table should be run back, and the cross-rail set parallel to the **V**'s, as described in Art. **62.** After this, a light cut should be taken over the table and the heads set to plane vertically.

In the case of very small planers, the beds are usually so stiff that very little, if any, adjusting is necessary when setting them up, all the adjustment being made by the manufacturer; but even in this case it is well to go through the entire series of tests, if accurate work is to be required from the machine.

69. Setting Heads.—The amount of accuracy required in setting the heads, either on a large or small planer, depends very largely on the character of the work to be done on the machine. If all the work will be simply roughing and surfacing, the zero mark h, Fig. 16, may be placed accurately enough by adjusting the head to any good try square and scribing the mark on the saddle; while if a large amount of angular work is to be done on the planer, all of the tests must be applied to see that the mark is accurately located.

ENGINE ERECTION

70. Equipment Necessary.—The manner of erecting an engine depends both on the equipment at hand and the style of the engine. Where medium-sized or heavy engines are to be erected, traveling cranes should be provided for handling the heavy parts, as they can accomplish the work much more quickly and easily than any other handling device, and also can command the entire erecting floor. The crane should have sufficient height of lift to place in position the highest parts of any machine built in the shop. Where very high work is to be erected, the base is sometimes set in a pit so that the highest parts will not come above the crane. This is especially the case in erecting vertical engines. Some shops making a specialty of vertical engines have two sets of traveling cranes, one above the other, the lower intended for handling the heavier pieces and the upper for handling the upper portion of the engine and the light pieces. If an engine should be so high as to interfere with the travel of the lower cranes, a crane may be set on each side of the engine before the cylinders are put up, so as not to cut off the rest of the erecting floor from the crane service while the high engine is in the shop. One advantage of having light, quick-motion traveling cranes placed well above the heavier cranes is that the upper cranes can lift light pieces above the lower cranes and carry them to any place on the erecting floor without interfering with the heavy work of the larger cranes.

71. All floors on which erecting is done should be firm and solid, to avoid any danger of the work being thrown out of line by settling when heavy parts are added. Before beginning work, the erecting floor should be cleared of all unnecessary obstructions and swept. The influence of the style of engine on the manner of erection will be brought out in the description of the horizontal and vertical types of engines. For the erection of small engines an iron-plate erecting floor on which the engine can be bolted down and tested is a great convenience.

HORIZONTAL STATIONARY ENGINES

72. Preparation of Bed.—The method of erecting a horizontal engine is not influenced greatly by the type of engine; that is, the work of erecting both Corliss and slide-valve engines is very similar. Before the engine bed is brought to the erecting floor it should be machined as far as possible, including the boring of the main bearing, if this is cast with the bed, and the scraping of the guides. The guides are usually scraped to a special surface plate, or to the crosshead itself, before the work is brought to the erecting floor, after which levels are placed on the guides and pillow-block bearings, and the bed is adjusted until it is level by means of wedges and leveling jacks.

73. Fitting Cylinder to Bed.—The cylinder is bolted to the bed or frame and a line or wire fastened to a piece of wood bolted to one of the studs in the end of the cylinder, as shown at *a*, Fig. 17. This line is carried through the cylinder, piston-rod stuffingbox, and guides, and fastened to the end of the frame in case the pillow-block is cast solid with the frame; or in the case of an engine in which the pillow-block is bolted to the frame, the line may be fastened to any suitable object, as, for instance, the angle plate and stick shown at *b*. The line should be set central with the bore of the cylinder at the back end by calipering from the inside of the cylinder to the line. An inside adjustable gauge or micrometer may be employed; but in most cases it is better to use a light pine stick like that illustrated in Fig. 18. The stick *a* is tapered at both ends and may have a pin *b* driven in at each end. The advantages of the stick in calipering are that it is lighter than the inside micrometer and is less affected by expansion and contraction than a metal gauge would be.

74. The line must also be brought central with the stuffingbox at the other end of the cylinder, by means of a stick similar to that shown in Fig. 18, but more quickly by use of the device illustrated in Fig. 19. This contrivance consists of a hardwood block *a*, which is turned to just fit the stuffingbox and has a $\frac{1}{4}$-inch hole *b* drilled in the center. The face of the block is

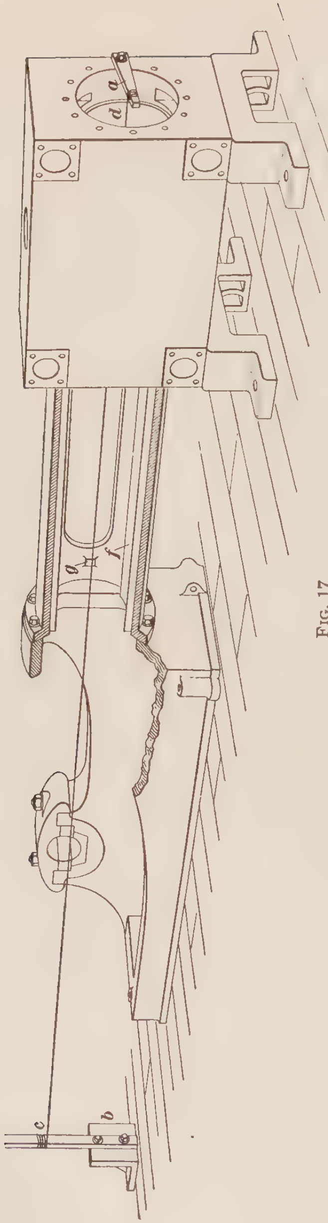


FIG. 17

turned square with the outside, and two center lines $c\,d$ and $e\,f$ are drawn across the face at right angles to each other. By sighting along the lines $c\,d$ and $e\,f$, it is easy to determine when the line or wire $c\,d$, Fig. 17, is central with the stuffingbox. The angle plate b is adjusted until the line $c\,d$ is central with the stuffingbox.

75. Lining Guides to Cylinder.—The guides may now be lined to the cylinder by measuring from the inside of the guides to the line at the top and bottom, as at f, Fig. 17, which will determine whether the line is central to the guides in a vertical plane. This test should be made at each end of the guides. In order to see whether or not the line is central horizontally, spots g are cast on the frame and faced off by the boring tool at the same time that the guides are bored.

Another and quicker method of lining the guides with the cylinder is to use a center block, as shown in Fig. 20. This block consists of a casting a that is turned to fit the inside of the guides. At the center there is a small hole b through which the line passes, and the lines $c\,d$ and $e\,f$ drawn at right angles to each other serve to locate the center

line in its proper position, this being done in a manner similar to that described in Art. **74.** When the center block shown in Fig. 20 is used, the spotting plates *g*, Fig. 17, are not necessary.

76. Bringing Cylinder in Line With Guides.—If the cylinder is not in line with the guides, the joint between the cylinder and guides must be so fitted as to bring them in line. The amount of adjustment necessary may be determined by slacking off the nuts on one side and introducing pieces of sheet metal until the cylinder and guides are brought into exact alinement. After this, an amount equal to the thickness of the metal introduced may be removed from the other side of the end of the cylinder or guides. When very small, this amount is sometimes removed by filing or scraping; when greater, by machining.

FIG. 18

77. To machine parts so accurately that the cylinder of a large engine can be brought in line with the guides without fitting, has been found practically impossible and for this reason many builders place a loose ring or spacing piece between the cylinder and the guides, and in the case of a tandem compound engine, between the high-pressure and low-pressure cylinders. After the amount of adjustment necessary has been determined, this distance piece is taken out and the proper amount removed from the high side. When this method is followed, care must be taken to mark the distance piece so that it cannot be placed in a wrong position. To insure this, at least one of the stud or bolt holes uniting the parts should not be located according to the regular spacing system, so that the castings cannot be put together in any but the correct position. This may also be accomplished by using guides or dowel-pins.

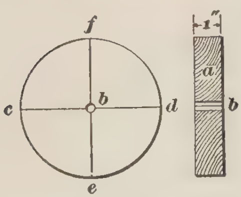


FIG. 19

78. Fitting Crank-Shaft.—After the cylinder and guides have been brought into perfect alinement, the crank-shaft is fitted. The outboard bearing may be very closely located by

stretching a line through the shaft bearings at right angles to the lines through the cylinder and guides. The journals of the shaft should then be wiped clean and given a coat of marking material. The shaft should then be placed in its bearings with the lower half of the boxes in position and turned a few revolutions. The shaft is then lifted out of the bearings and the high spots scraped off with a half-round scraper. This operation is repeated until the shaft shows a good bearing in both the main pillow-block and the outboard bearing. After the lower half of each box is scraped, the upper halves may be put in place and fitted in like manner. The shaft is then taken from the bearings and the cranks pressed or shrunk on

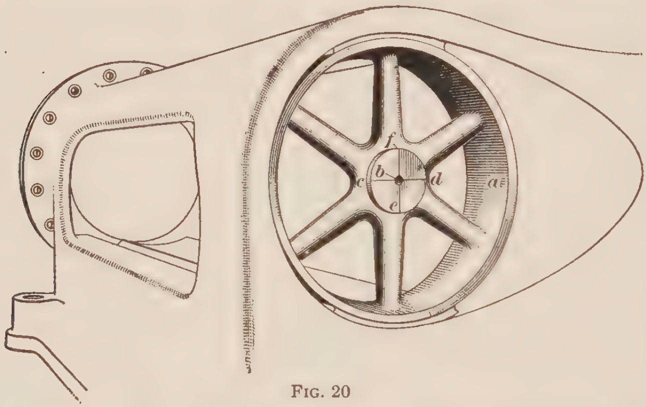


Fig. 20

and keyed. The eccentrics and governor-driving device are also placed in position, after which the shaft is returned to its place.

79. To make sure that the crank-shaft is exactly at right angles to the center line of the engine, and also horizontal, the following course may be pursued: The crankpin *a*, Fig. 21, is brought up to the center line *c d* of the engine and a piece of wood *b* is fitted between the face of the crank *e* and the head of the crankpin *f*. A mark is made on this piece of wood in the middle, and this mark should coincide with the center line *c d*. If they do not coincide, the outer end of the crank must be moved until they do. The shaft is now turned a half revolution to

bring the crankpin under the line at the other end of its travel, as shown by the dotted lines at a'. If the line on the stick b again coincides with the center line $c\,d$, the shaft is at right angles to the center line of the engine. To test the shaft to see whether it is level or not, a fine plumb-line may be hung vertically before the shaft and the crankpin a brought in contact with it at the upper portion of its revolution, and then tested again at the bottom of the revolution. If the crankpin just touches the line at both the top and the bottom, the shaft is horizontal.

80. Fitting Reciprocating Parts.—After the engine is lined up and the shaft is square and level, the reciprocating parts may be put in place. The piston, with its piston rod attached,

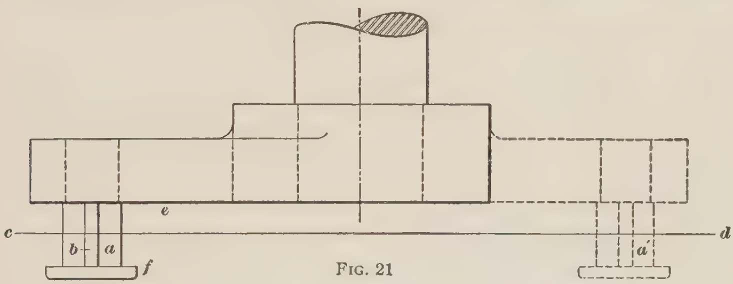


FIG. 21

is slipped into the cylinder and the crosshead into the end of the guides. The piston rod passes through the bushing in the head of the cylinder and is secured to the crosshead. These parts should be tested as they are put in place, to see that they line up properly. Some makers use a crosshead of such a pattern that the line $c\,d$, Fig. 17, may be carried through it and used in testing the crosshead to see that it lines up properly. After the crosshead and piston rod are in place, the connecting-rod may be put on. Before any of the surfaces that are to slide or move on one another are placed in contact, they should be well oiled. The oiling devices are put in place as fast as the parts are ready for them.

81. As the control of the movements of the engine depends on the governor, consequently, great care should be taken to

see that there is no danger whatever of its sticking or failing to act. To insure its perfect operation, the governor should be assembled separately and belted up so as to run at about its normal speed. The gears should be fitted so as to run as quietly and as smoothly as possible, and the dashpots, weights, and all parts properly adjusted during this preliminary run. It is usually best to run the governor one or two days in this way. After the governor has been fully adjusted, it may be taken down and placed on the engine. If the engine is a Corliss engine, the dashpots are responsible for the closing of the valves, and hence they should be assembled and tested before being placed on the engine. Shops building this class of engines usually have some device in which they can place a dashpot and run it for some time while adjusting it. After the dashpots are fully adjusted they are placed on the engine.

82. Devices for Oiling and Other Small Parts.—The oiling devices for the crankpin, eccentrics, crosshead, governor, and all other parts are put in place as fast as the parts are ready to receive them, and they should all be tested before steam is let into the engine.

83. Fitting Flywheel.—For small engines flywheels are made either solid or in halves. If made solid, the flywheel must be placed on the crank-shaft before this is lowered into the bearings. In some cases there is not room in the shop to put the flywheel in position, and the engine is assembled without the flywheel being placed on the shaft. Where it is possible, it is best to erect the flywheel with the engine. In erecting a large built-up flywheel, the hubs and hub flanges are placed on the shaft first. The arms and segments of the rim are then attached one at a time. By beginning the work on one side, the arms and sections of the rim may be attached to the hub flanges near the floor level, thus doing away with the necessity of raising them to any great height. After one arm and section of the rim are put in place, they may be lowered into the pit and the next one in order connected. This process may be continued until the wheel is completed. When the work is done under a traveling crane, it is usually more convenient to place each of the

arms and segments at the top of the wheel and then lower them far enough to make room for the next.

84. Use of Dowel-Pins.—Whenever it is necessary to make the bed of an engine in sections, or when any parts require accurate alinement, they should be doweled together by drilling holes through the pieces and reaming them out with a taper reamer after the work is erected. After the holes are drilled and reamed, taper pins are fitted to them. These pins are usually given a taper of from $\frac{3}{8}$ to $\frac{3}{4}$ inch per foot. As each part is put in place, it should be clearly and distinctly marked by letters, figures, and lines, so that it may be easily returned to its position when erecting in the field. If the work is complicated, a record should be kept of the marks used so as to avoid confusion in the final erecting.

85. Lagging Steam Cylinders.—*Lagging* is the wooden, sheet-steel, or cast-iron covering put on steam-engine cylinders. It gives the cylinder a finished appearance and protects the inner covering, composed largely of asbestos, which is put on the cylinder to prevent the loss of heat. This non-conducting covering may be either applied in the shop previous to shipment, or in the field. The supports for the lagging are first secured to the cylinder, after which the asbestos mortar is prepared and applied to the cylinder. The mortar is spread evenly over the cylinder in such thickness as will not interfere with the lagging when attached. The cylinders are generally heated with steam when putting on the mortar, in order to dry it.

When cast-iron lagging is used, it is cast in sections and fitted to the cylinder. When sheet-steel lagging is employed, it is, when possible, cut to the right dimensions and rolled into a cylindrical form, or it is sheared to the proper size, if the cylinder is to be lagged square. The lagging sheets are finished by hand work. The screw holes in the sheets are generally drilled in a drilling machine. The sheet is clamped in place while the holes are marked off, after which the lagging supports are drilled and tapped. When the cylinder attachments have all been put in place and the cylinder tested, the lagging is put on.

86. Painting and Finishing Engine.—All rough places on the bed are smoothed off by chipping and filing before painting; in some cases the bed is given a coating of filling material that fills all depressions. After the bed has been filled and rubbed down with sandstone or sandpaper, it is painted. The specifications sometimes call for the testing and acceptance of the engine before painting.

87. Dismantling.—When the work is passed or pronounced correct by the superintendent or inspector, the man in charge of the erection of the engine oversees the taking down and prepares the parts for shipment. The lagging is usually removed and boxed. All small parts are also boxed. These boxes should be numbered and a careful record kept of their contents. The cylinder, in the case of large engines, is mounted on skids. All finished parts of the work are given a coating of some protective material, such as slushing oil or white lead and tallow that will prevent rusting. The bearings and fitted surfaces are boxed or covered with boards to protect them from injury. Crankpins and main shafts are sometimes wrapped with burlap or rope, and if large and finely finished, they may be lagged with wooden strips. In the case of comparatively small engines, the entire engine is sometimes placed on skids. If the machinery is to be shipped by rail the heavy parts of the load should come over the trucks, the lighter parts, boxes, etc. being located near the center of the car. All parts should be securely fastened, so that they cannot shift during shipment.

88. Foundation-Bolt Templet.—While the engine is being erected in the shop, a templet for locating the anchor bolts in the foundation is made. This templet should include the correct location of all bolts for securing the engine bed, cylinders, and outboard bearing to the foundation, and in the case of a large and complicated machine like a hoisting engine, should also include the bolts for the steam brake, steam reverse, drum-shaft bearings, etc. The templet is usually laid out from the drawing, after which all the dimensions should be checked by actual measurements of castings, to see that there is no discrepancy between the drawing and the casting. After

the holes have been properly laid out, they are bored the same size as the anchor bolts. This templet is usually made of 1-inch white-pine lumber and must be thoroughly braced. The parts should be put together in a substantial manner with screws or bolts, or both, and also marked so that after being taken apart for packing and shipment the templet can be easily and accurately assembled at the foundation pit. Fig. 22 shows a plan of such a templet.

89. Foundations.—The foundations may be composed of masonry, brick, or concrete. Stone and brick should be laid in good cement mortar. The bolts may be built into the foundation or pockets may be left at the bottom for the washers and nuts, and holes left for introducing the bolts

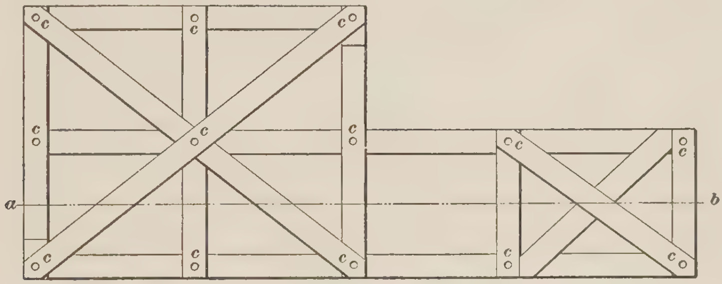


Fig. 22

later. In some cases, these holes may be made by building wooden boxes or iron pipe into the foundation. In still other cases, the foundations are built with pockets near the bottom, and then the masonry or concrete built up solid, after which the bolt holes are drilled with a diamond drill. When the foundation is made of concrete it is usually better to build the bolts into it. In small work burlap may be wrapped around each bolt, forming a bunch, and these bunches are then raised along the bolts as the brickwork or masonry progresses, thus leaving clearance spaces around the bolts.

90. The anchor bolts may be held down in a variety of ways. Sometimes a large washer is placed on the lower end of each bolt. In other cases a stirrup is formed at the lower ends of

the bolts and pieces of railroad iron passed through these, as shown at *a*, Fig. 23. The pieces of iron may be long enough to extend through the stirrups of two or more bolts at once. The foundation-bolt templet *b* is supported on suitable blocking in a level position and rigidly braced to support the bolts. Sometimes it is necessary and best to suspend the templet by braces from overhead supports. The rails *a* should be wedged against the bottom of the stirrups *c* by driving wedges on top, as shown at *d*. To allow some adjustment of the bolts, a piece of pipe may be placed about them, as shown at *e*.

91. Appliances for Erecting Engine on Foundation. The engine is sometimes erected on the foundation by the man who did the erecting in the shop, where the erector has the advantage of all the shop tools and appliances. including cranes, special tools, etc. When the engine is shipped from the works,

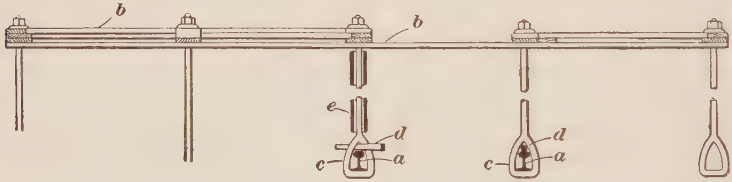


Fig. 23

the man who is to go with it selects such tools as he requires. The tools needed vary greatly with the work and with the locality in which the engine is to be erected. Most modern power houses have traveling cranes in the engine rooms that can be used in erecting the engine or for any future repair work. In this case very few tools will be required. If the engine is to go into a region a long distance from any shop, as, for instance, a mining camp, the erector must take practically everything with him that he will require. Usually one or two hydraulic or ratchet jacks, a few screw jacks, and some pinch bars will be all of the larger tools necessary; a liberal stock of heavy ropes, wrenches, hammers, chisels, and other tools that may be needed should also be taken. If heavy parts must be hoisted some distance, it may be necessary to take a chain block or other hoisting devices. Sometimes it is conve-

nient to take a stock of rollers and blocking, but usually these can be obtained in the field.

92. Setting Engine on Foundation.—The engine bed and cylinder are placed on the foundation and bolted together. All the dowel-pins are fitted and the engine is lined up by stretching a line through the cylinder and beyond the crank, just as was done in the shop. The engine can be supported on iron wedges during this operation. The outboard bearing can be put in place and squared by means of the crank, as described in Art. **78.** After the bedplate is properly located over the anchor bolts, the clearance spaces left around the bolts in the masonry should be filled with cement. This cement is mixed, the same as that used under the engine bed, as noted below. Enough water is added to the cement mixture so that it will flow readily into the holes. In large work with removable bolts, the cementing is not required. After the engine has been bolted together and lined up, the space between the bottom of the bedplate and the foundation may be filled with some suitable grouting. Usually Portland cement mixed in a proportion of 1 part of cement to 2 parts of sand is used; but if no cement is available melted sulphur, or a mixture of iron chips and sal ammoniac rammed in with a calking chisel, may be employed. When the grouting has hardened, the flywheel or pulley may be put in place and the caps over the bearings adjusted. All parts subjected to friction should be thoroughly oiled before being put into place, as an unoiled surface sometimes cuts during the first few revolutions before the oil reaches it through the oil hole. The piston, cross-head, connecting-rod, cylinder head, governor, valve gear, oiling devices, lagging, and piping are assembled in the order named.

93. The engine may now be turned a full revolution by hand to make sure that all is clear. Next, care should be taken to see that everything is in adjustment; then the steam may be turned on and the engine started very slowly. After the engine is started with steam, a thorough inspection of all working parts should be made and all the oiling devices properly adjusted. Any parts that have been left too loose may now

be tightened to proper running fits, and any part that shows a tendency to heat should be examined and adjusted. After the engine has been running at full speed for some time, it may be belted up and kept at work while it is tested.

VERTICAL STATIONARY ENGINES

94. The method followed in erecting a vertical engine does not differ materially from that used in the horizontal engine; but as the parts are differently arranged, and in most cases some additional parts are required, a description showing the principal points of difference will be given. As a rule, it is more difficult to erect a vertical engine without the aid of cranes or hoists than a horizontal engine. Very large horizontal engines are frequently erected in the field without any hoisting tackle whatever, all the parts being moved on rollers and lined up by means of jack-screws. In the case of a vertical engine, it is usually necessary to rig a derrick, shear legs, or some hoist when in the field.

95. Work Necessary on Bed.—The bed *a*, Fig. 24, is leveled by means of wedges or erecting jacks, as in the case of a horizontal engine. The bearings for the crank-shaft may be scraped either before or after the guides are in place. Sometimes, to aid in scraping these bearings, a hollow cast-iron shaft is made of the same diameter as the crank-shaft. This is lighter than the crank-shaft and serves as a surface plate for scraping the bearings into line.

96. Fitting Guides and Cylinders.—The frames and guides *d* and *d'*, Fig. 24, are placed on the bed and temporarily bolted down. A center line along the center of the shaft is established by placing blocks across the bearings, as shown at *e*. A piece of tin is fastened to the center of each of these and a center line marked on it. A long straightedge is then laid across both blocks and a center line established. A line, as *f g h i*, is stretched through each cylinder. The line is secured at the bottom to a plank *j*, which is blocked or clamped to the bottom of the bedplate and has a hole in the center through

which the line passes. At the upper end, above the cylinders, the line is secured to the plank *k*. The line passes over pulleys at *g* and *h*, and is kept taut by a heavy weight at *i*; a piano wire capable of standing a breaking stress of 400 pounds is usually used for this purpose, and the weight at *i* may vary from 100 to 200 pounds. This weight should be located so that no damage will be done if the wire should break. After the line is established, the guides and cylinders are adjusted to it. If desired, the weight at *i* may be hung under the cylinders in

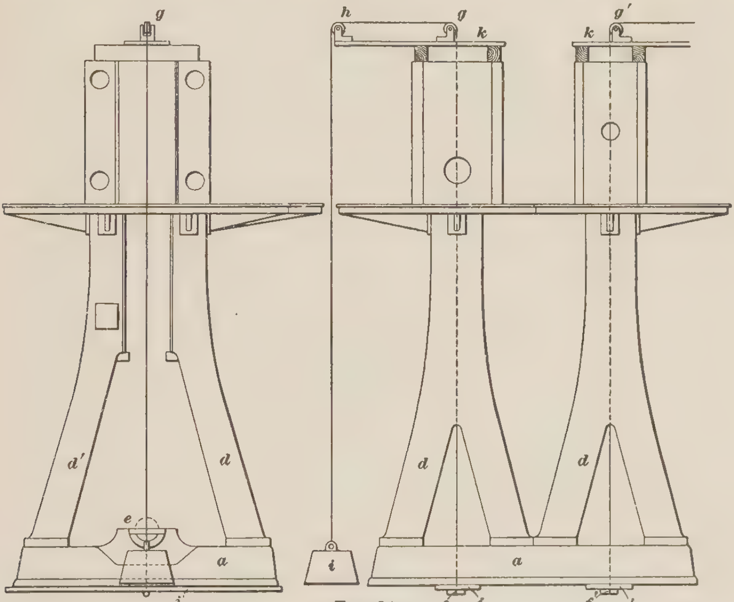


FIG. 24

place of the plank *f*. To prevent vibration, the weight should be suspended in a vessel of water. Great care must be taken to see that the lines *f g* and *f′ g′* are the same distance apart, both top and bottom, and are in the same vertical plane.

If the cylinder does not come in line with the guides, packing pieces must be placed between the cylinder and the guides, as in the case of a horizontal engine, after which a sufficient amount must be dressed from the end of the cylinder or the intermediate piece, to bring the two into alinement. In measuring

from the line to the cylinders, or from the line to the guides, a wooden measuring piece may be used, as described in Art. **73.** After the cylinders and guides are properly located, they are securely clamped in place, and the bolt holes for holding the uprights to the bed, the guides to the uprights, if the latter are made separate, and the cylinders to the guides, are reamed ready for the bolts. The holes for the dowel-pins are drilled and reamed and the pins fitted.

97. Placing Reciprocating Parts.—The placing of the reciprocating parts of vertical engines does not differ materially from that of horizontal engines, and the method of squaring the crank-shaft to the center line that is used in the horizontal engine can also be employed in the vertical engine.

98. Devices for Oiling and Smaller Parts.—In some cases, vertical engines are fitted with separate oiling devices for each bearing, while in other cases an oil tank is arranged at or near the cylinder from which pipes lead to the various bearings. Another system provides a reservoir with a pump, either attached to the engine or as a separate machine, which distributes the oil through a suitable arrangement of piping. All these devices are placed in position during erection. Since many parts of the engine are not accessible from the floor, some device must be provided by means of which the attendant can reach any part of the engine. For this purpose, platforms or floors are built around the engine at different elevations. The platforms are usually iron plates supported on brackets, and are reached by staircases leading from the floor of the engine room. The brackets and plates are all placed in position as the various parts of the engine are being assembled. Standards, which carry a hand rail, usually composed of brass or iron pipe, may be attached to the outer edges of the plates. Large vertical engines are often provided with hand or similar turning gear for turning the engine a portion of a revolution in starting or when fitting belts. They are also supplied with steam, vacuum, and revolution gauges, and a clock, which are attached to the engine frame, though they are not generally assembled in place

until the engine is erected on its foundation; or they may be erected on a board entirely separate from the engine. The steam indicator is also attached to the engine.

99. Dismantling.—After an engine has been erected and tested, it is dismantled in a manner similar to that used in taking down large horizontal engines, except that it must be done to a greater extent; that is, owing to the greater height of the vertical construction, more parts must be detached and shipped separately.

100. Permanent Erection.—The erection of a vertical engine on the foundation does not differ materially from that of a horizontal engine, except that in some cases no line is stretched through the engine when it is erected on the foundation, bolts and dowel-pins being depended on entirely for bringing the parts into line. In erecting a vertical engine, the bedplate must be carefully leveled and have a firm bearing before the other heavy parts are assembled on it.